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OF THE

BIRMINGHAM NATURAL HISTORY

AND

PHILOSOPHICAL SOCIETY.

NATURAL HISTORY SOCIETY, FOUNDED 1858.
PHILOSOPHICAL SOCIETY, FOUNDED 1876.
AMALGAMATED 1894.

"NATURÆ SPECIES RATIOQUE."
Lucretius.

VOLUME IX.—PART I. 12

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OF THE

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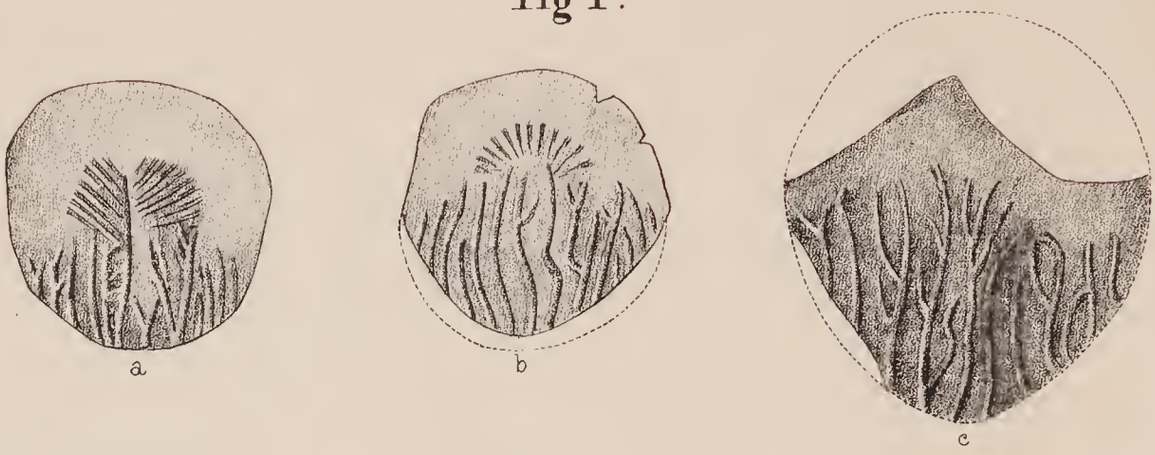

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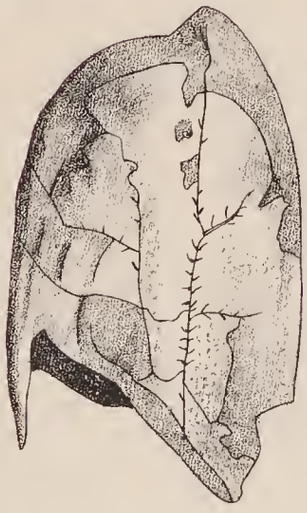

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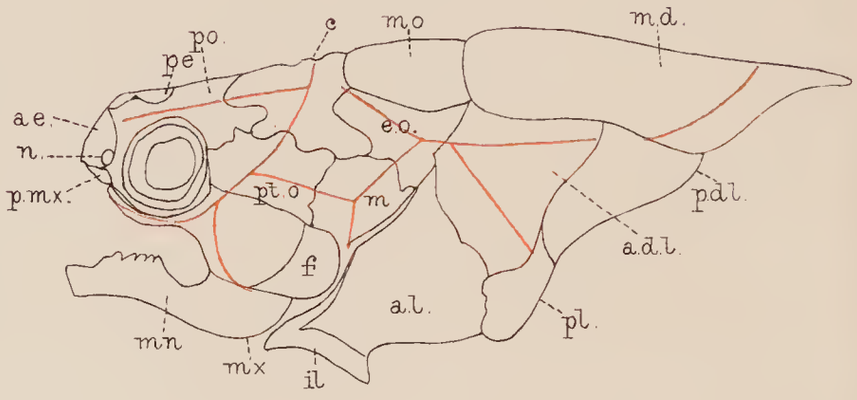

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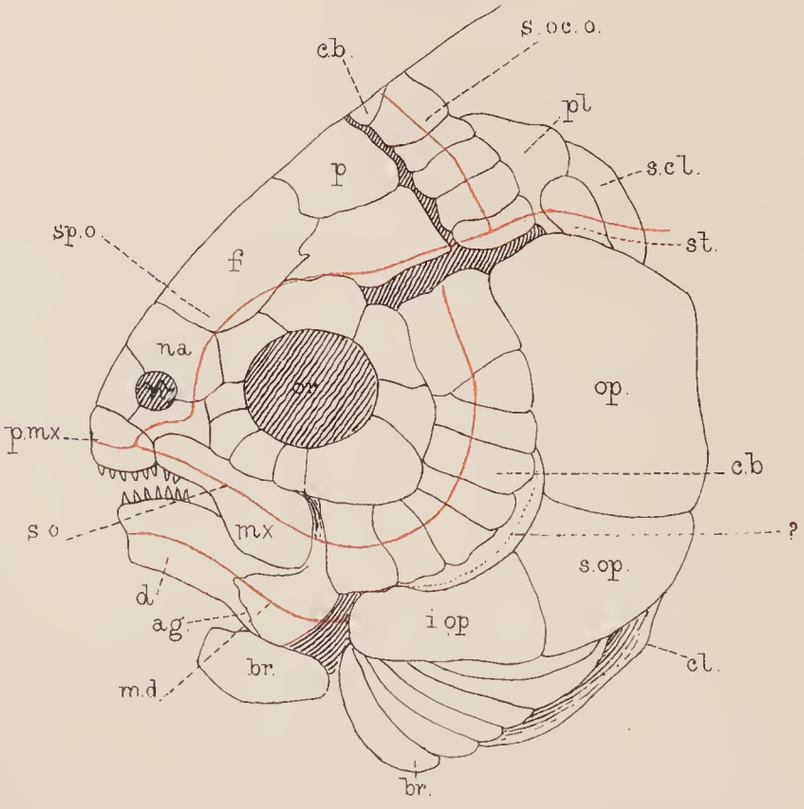

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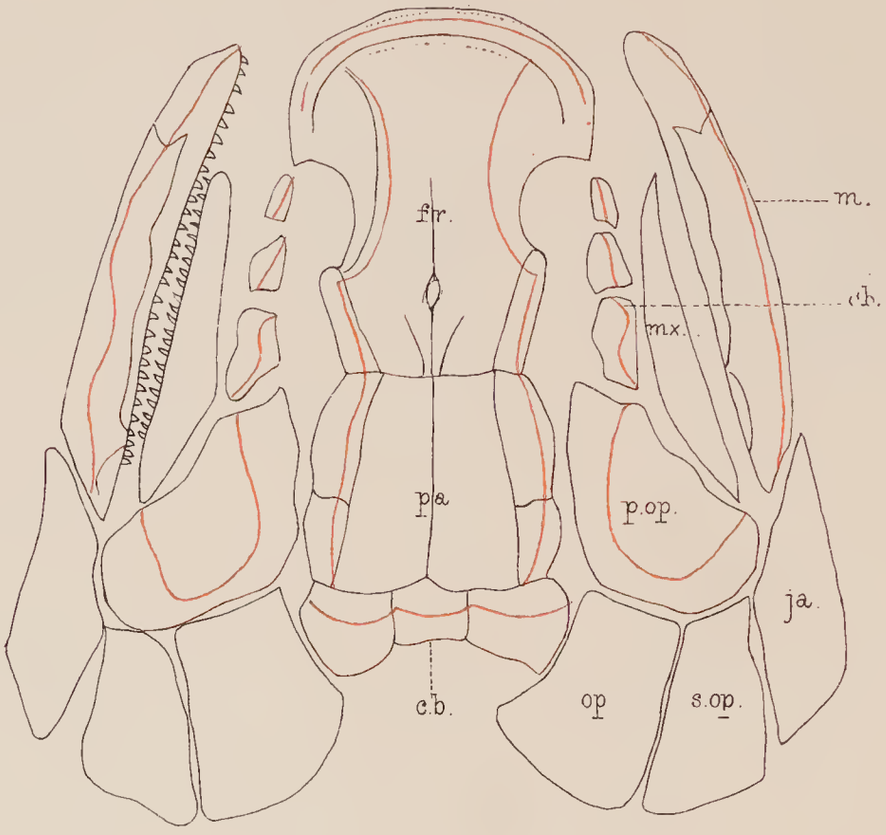

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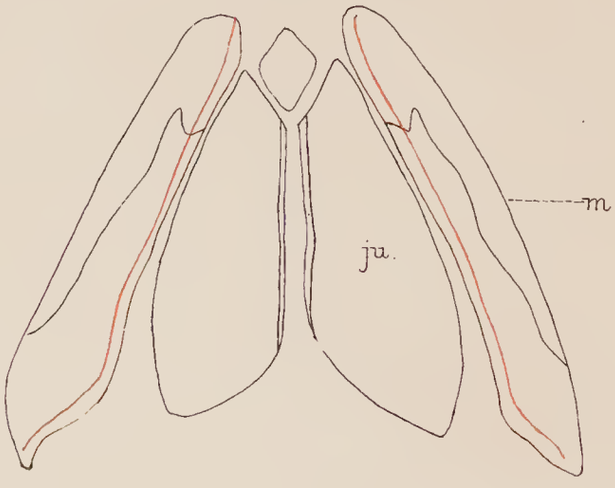

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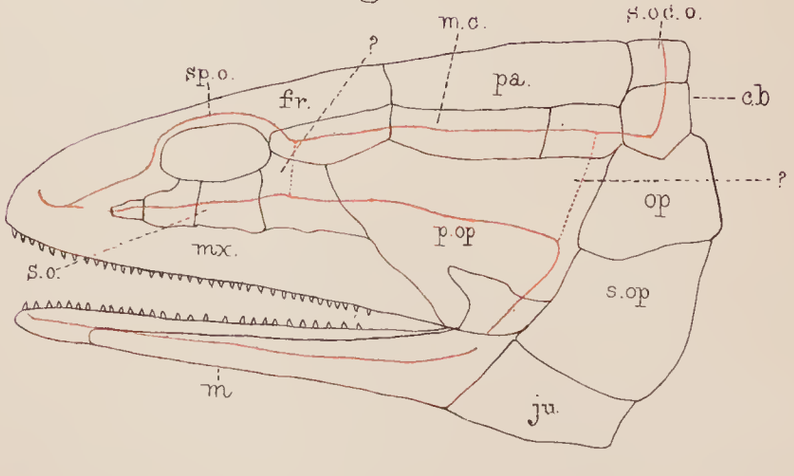

PROCEEDINGS

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BIRMINGHAM NATURAL HISTORY

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VOL. IX.—Part I.

EIGHTEENTH SESSION, 1893—94.

I.—*A History of the Methods of Weighing the Earth.*

By Professor J. H. Poynting, D.Sc., F.R.S.,

President of the Society.

[Presidential Address, October 19th, 1893.]

It has been the custom, followed usually by my predecessors, to select for the subject of the annual address some general scientific or educational topic. My reason for departing from this custom is twofold. In the first place, I feel more competent to address you on a subject which has been my special study for some years, and perhaps I may have the best chance of interesting you in that in which I am most interested; and in the second place, I shall by this course economise the time of

the Society. Some months ago the Council honoured me with a request that I should give the Society some account of an experiment which I had recently completed on the weighing of the earth. At that time all the ordinary meetings were fully occupied, and I could not arrange to give the account asked for. It occurred to me that I might appropriately give you, this evening, a history of the many experiments which have been made to weigh the earth, and at the same time comply with the request of the Council by giving you most detail with regard to the method with which I am best acquainted.

When we speak of "weighing the earth," it is obvious that we are not to interpret the expression quite literally, for the weight of any substance means primarily the pull of the earth upon it. When we weigh out a pound of tea or a ton of coal we always use *the pull of the earth* to measure the pound or the the ton, finding how much brass or iron is equally pulled. The earth cannot be weighed in this sense, for it pulls itself equally in all directions, so that the net result is no pull at all.

But in general we do not want to know the weight of a body except as a step towards knowing its mass, that quality which tells us what effect force has on it, how difficult it is to set in motion.

The weight—the actual earth pull—varies from point to point of the earth's surface. The mass is everywhere and through all time the same.

It is the mass which really interests us, and which we think of when we make purchases by weight. If we buy a pound of tea in London it is no satisfaction to know that here at home it will be pulled by the earth so that it is a quarter of a grain heavier. For all our purposes it is the same quantity of tea here as there.

So with the earth, it is the mass which we really mean when we speak of its weight. Though we cannot directly weigh it to find the mass, we can think of an imaginary experiment which would give us the mass by weighing, could we only carry it out; and perhaps the imagining of this experiment may render

rather more real the idea of the earth's mass. Suppose, then, that we could bring up the earth, a cubic foot at a time, to a certain place, weigh each cubic foot as it was brought up, and then replace it, so that the earth was never diminished by more than a cubic foot at a time; the total weight of all the cubic feet would give us the mass of the earth in pounds or tons.

But it is sufficiently evident that no approach to such an experiment is possible, and we must look for some other way to measure the mass. The way is found in the pull, the weight, which the earth gives to bodies on its surface. That pull is, of course, a particular case of gravitation, the attraction which exists, as we know from astronomical and terrestrial observation, between every two parts of matter. And Newton proved that the two pulls exerted on the same piece of matter by two bodies are in proportion to their masses, and inversely as the squares of their distances away from it. If, then, we can hang up a weight and find the pull of the earth on it, and then bring up another body large enough and near enough to exert an appreciable pull upon the hanging weight, by comparing the two pulls and allowing for the different distances, we can find how many times greater is the mass of the earth than that of the body brought up.

To put this in a concrete form—the form it has actually taken in an experiment to be described later—suppose we have a weight of 50lbs. hung on to a balance (Fig. 1); the earth pull is

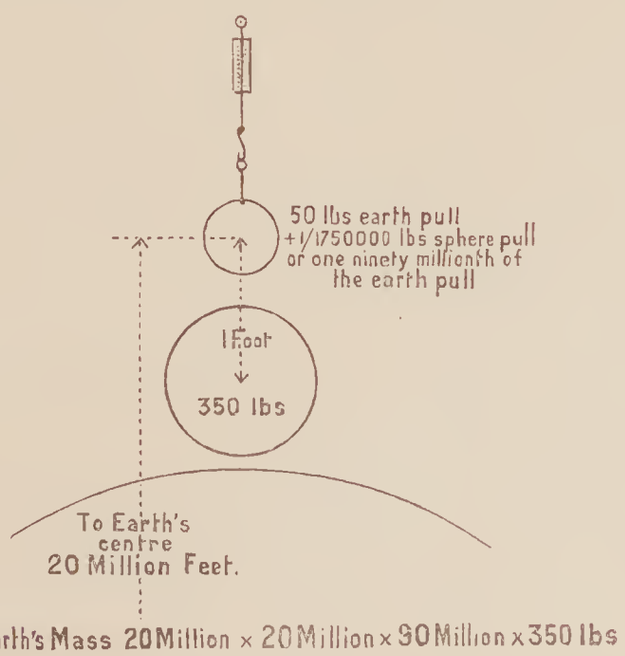

Fig. 1.

its weight of 50lbs., and the earth on an average is 20,000,000 feet away. Now bring up a sphere weighing about 350lbs., and at an average distance away of one foot. The 50lbs. is found to weigh more by about $\frac{1}{250}$ grain, *i.e.*, the sphere pull on it is $\frac{1}{250}$ grain, or $\frac{1}{1750000}$lb. Hence the earth pull is about ninety million times the sphere pull; but it is twenty million times as far away, so that at the same distance, one foot, the pull would be 400 billion times greater still. Hence the mass of the earth is 400 billion times 90 million times the 350lb. mass of the sphere. This arithmetic sounds much worse than it is, and the result easily comes out that the mass of the earth is about

12,500,000,000,000,000,000,000,000lbs.

A large number of this kind is practically very troublesome, and it is much easier to express the result by saying how many times greater is the mass of the earth than that of an equal globe of water. The earth has a radius of about 20,000,000 feet; whence, allowing 62·4lbs. to each cubic foot, we easily find that its mass is about 2,300,000,000,000,000,000,000,000lbs., so that the earth weighs $5\frac{1}{2}$ times as much, or its mean density is $5\frac{1}{2}$ times that of water.

The principle of all the methods of weighing the earth is that which I have tried to explain by this example. A weight is hung up, and the pull on it by some body of known mass at a known distance is compared with that exerted by the earth. We may have a specially prepared mass under or at one side of the hanging weight, or we may use a part of the earth itself, such as a mountain, of which, by careful examination, we can estimate the mass. In this case, the hanging weight is placed at one side of the mountain, and is observed to be drawn aside from the line in which it would have hung, towards the mountain (Fig. 2). The distance it is drawn aside bears the same proportion to the length of the string as the pull of the mountain to the pull of the earth.

These methods of experimenting on the subject were clearly indicated by Newton, the discoverer of the law which

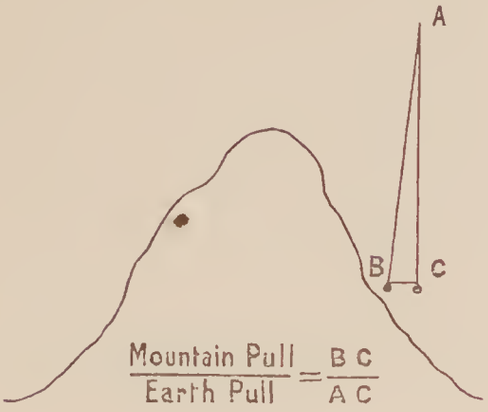

Fig. 2.

makes them possible. But he thought that the attraction of a sphere, such as I have described, would be far too small to measure, partly, no doubt, through the fact that he made a mistake in his arithmetic, which led him to estimate the attraction at less than a millionth of its true value. He also calculated what kind of deflection sideways might be expected in a plumb-line on a mountain side, and again, though his arithmetic was correct, he thought the result too small to measure. He merely contented himself with a guess at the mean density. But Newton's guesses were as good as other people's work, for when he estimated that the density was five or six times that of water, the value was, at least, as definite as our experimental knowledge till within the last twenty years.

The first actual measurements were made about 1740, in the course of another celebrated piece of work which first definitely decided the shape of the earth. According to Newton's theory of the earth, its form should be nearly a sphere but slightly flattened at the poles. Certain measurements, made about 1700, had pointed to the shape of a sphere slightly drawn out at the poles, and to settle the question the French academy sent out two commissions, one to Lapland, and another to Peru, to measure the length of a degree of latitude in each place. It is easily shown that if the earth is flattened at the poles the degree in northern regions should be longer than at the equator. The Lapland degree proved decidedly longer than the Peruvian one, and so it was definitely settled that the earth is a flattened sphere.

There is a curious story in connection with the Peruvian measurements told by Whymper. They were based on a length carefully measured from one point to another by measuring rods, and the commission, thinking doubtless that this length should stand as an eternal monument of their work, erected pyramids exactly over the two ends to fix the points. But the Spanish Government, its pride apparently offended by the inscriptions on the pyramids, destroyed them as soon as the commission returned to France. Later they were replaced, and in 1880 Whymper found one of them still in position. A former President of Ecuador had removed the other some hundreds of feet to one side in order that it might be better seen.

In the course of their labours the Peruvian commission made other important scientific investigations, and one member, M. Bouguer, had the happy idea of measuring the variation in weight due to the enormous masses of the Andes. He worked in two ways. In one series of experiments he determined the rate of swing of a pendulum of fixed length at the sea level, at Quito, a town on a table-land nearly 10,000 feet high, and on the summit of Pichincha, above Quito, and nearly 16,000 feet high. These last are the highest pendulum experiments, I believe, ever made. Now, the time of swing of a pendulum increases as gravity decreases, and, supposing the earth to be a smooth sphere all at sea level, the decrease due to a rise in height to Quito, nearly 10,000 feet above that level, should be about 89 in 100,000; but the pendulum showed that gravity did not decrease so much. In fact, it was greater than the calculated gravity by about 12 in 100,000. This excess was due to the down pull of the table-land on which Quito stands, or the pull of the piled-up mass was to that of the whole earth as 12 to 100,000, say 1 to 8,000. Now, had the table-land been of the same density as the earth, a calculation from its size and distance from Quito showed that its attraction should have been about four times as great as this. Hence, from Bouguer's work, the earth would appear to be four times as dense as the mountain, a result we now

know to be much too great. No doubt the means at Bouguer's command were inadequate for accurate work.

Bouguer also used another method, estimating the sideway attraction of Chimborazo, a mountain about 20,000 feet high, on a plumb-line placed at a point on its side. Fig. 3 will

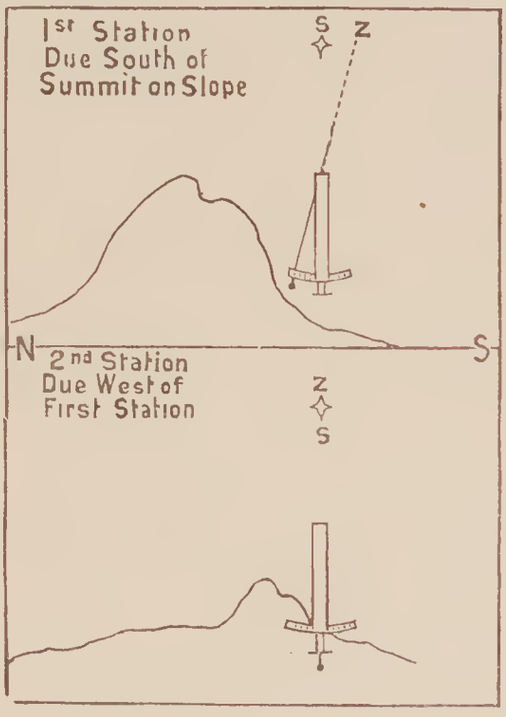

Fig. 3.

show the principle of the method. Suppose that two stations are fixed, one on the side of the mountain due south of the summit, and the other on the same latitude, but some distance westward, away from the influence of the mountain. Suppose that at the second station a star is observed to pass the meridian—we will say, for simplicity—directly overhead, then a plumb-line hung down will be exactly parallel to the observing telescope. At the first station, if the mountain were away, it would also hang down parallel to the telescope when directed to the same star. But the mountain pulls the plumb-line towards it, and changes the overhead point so that the star appears to northward instead of in the zenith. The method simply consists in determining how much the star appears to be shifted to the north.

To carry out the experiment, Bouguer fixed the first station on the south slope of Chimborazo, just about the

perpetual snow line, and the second nearly on the same level, several miles to the westward. He describes how his expedition reached the first station after a most toilsome journey of ten hours over rocks and snow, and how, when they reached it, they had all the time to fight against the snow, which threatened to bury their tent. Nevertheless, they succeeded in making the necessary observations, and a few days later, they were able to move on to the second station. Here they hoped for better things, as they were now below the snow line. But their difficulties were even greater than before, as now they were exposed to the full force of the wind, which filled their eyes with sand and was continually on the point of blowing away their tent. The cold was intense; and so hindered the working of their instruments that they had to apply fire to the levelling screws before they could turn them. Still they made their observations, and found that the plumb-line was drawn aside about 8 seconds. Had Chimborazo been of the density of the whole earth, Bouguer calculated that it would have drawn aside the vertical by about twelve times this, so that the earth appeared to be twelve times as dense as the mountain, a result undoubtedly very far wide of the truth. But it is little wonder that under such circumstances the experiment failed to give a good result, and all honour is due to Bouguer for the ingenuity and perseverance which enabled him to obtain any result at all. At least he deserves the credit of first showing that the attraction by mountain masses actually exists, and that the earth, as a whole, is denser than the surface strata. As he remarks, his experiments at any rate proved that the earth was not merely a hollow shell, as some had till then held; nor was it a globe full of water, as others had maintained. He fully recognised that his experiments were mere trials, and hoped that they would be repeated in Europe.

Thirty years later his hope was fulfilled. Maskelyne, then the English Astronomer Royal, brought the subject before the Royal Society in 1772, and obtained the appointment of a committee "to consider of a proper hill whereon to try the

experiment, and to prepare everything necessary for carrying the design into execution." Cavendish, who was himself to carry out an earth-weighing experiment some twenty-five years later, was probably a member of the committee, and was certainly deeply interested in the subject, for among his papers have been found calculations with regard to Skiddaw, one of several English hills at first considered. Ultimately, however, the committee decided in favour of Schiehallion, a mountain near Rannoch, in Perthshire, 3,547 feet high. Here the astronomical part of the experiment was carried out in 1774, and the survey of the district in that and the two following years. The mountain has a short east and west ridge, and slopes down steeply on the north and south, a shape very suitable for the purpose.

Maskelyne, who himself undertook the astronomical work, decided to work in a way very like that followed by Bouguer on Chimborazo, but modified in a manner suggested by him. Two stations were selected, one on the south, and the other on the north slope. A small observatory was erected first at the south station, and the angular distance of some stars from the zenith, when they were due south, was most carefully measured. The stars selected all passed nearly overhead, so that the angles measured were very small. The instrument used was the zenith sector, a telescope rotating about a horizontal east and west axis at the object glass end, and provided with a plumb line hanging from the axis over a graduated scale at the eye-piece end. This showed how far the telescope was from the vertical.

After about a month's work at this station, the observatory was moved to the north station, and again the same stars were observed with the zenith sector. Another month's work completed this part of the experiment. Fig. 4 will show how the observations gave the attraction due to the hill. Let us for the moment leave out of account the curvature of the earth, and suppose it flat. Further, let us suppose that a star is being observed which would be directly overhead if no mountain existed. Then evidently at S. the plumb line is pulled to the

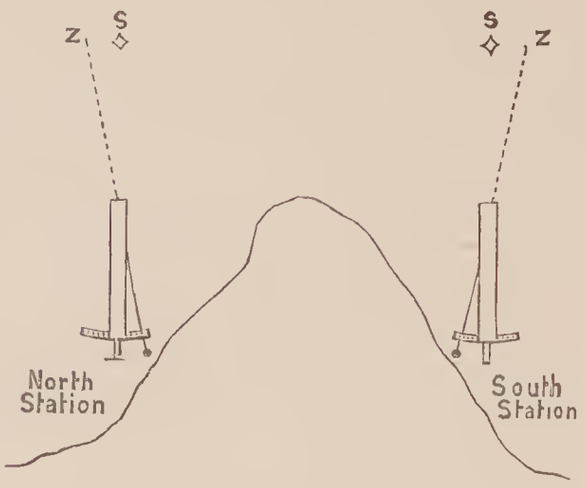

Fig. 4.

north, and the zenith is shifted to the south. The star therefore appears slightly to the north. At N. there is an opposite effect, for the mountain pulls the plumb-line southwards, and shifts the zenith to the north; and now the star appears slightly to the south. The total shifting of the star is double the deflection of the plumb-line at either station due to the pull of the mountain.

But the curvature of the earth also deflects the verticals at N. and S., and in the same way, so that the observed shift of the star is partly due to the mountain, and partly due to the curvature of the earth. A careful measure was made of the distance between the two stations, and this gave the curvature deflection as about 43″. The observed deflection was about 55″, so that the effect of the mountain, the difference between these, was about 12″.

The next thing was to find the form of the mountain. This was before the days of the Ordnance Survey, so that a complete survey of the district was needed. When this was complete, contour maps were made, giving the volume and distance of every part of the mountain from each station. Hutton was associated with Maskelyne in this part of the work, and he carried out all the calculations based upon it, being much assisted by valuable suggestions from Cavendish.

Now had the mountain had the same density as the earth, it was calculated from its shape and distance that it should have

deflected the plumb lines towards each other through a total angle of 20·9″, or $1\frac{4}{5}$ times the observed amount. The earth, then, is $1\frac{4}{5}$ times as dense as the mountain. From pieces of the rock of which the mountain is composed, its density was estimated as $2\frac{1}{2}$ times that of water. The earth should have, therefore, density $1\frac{4}{5} \times 2\frac{1}{2}$ or $4\frac{1}{2}$. An estimate of the density of the mountain, based on a survey made thirty years later, brought the result up to 5. All subsequent work has shown that this number is not very far from the truth.

An exactly similar experiment was made eighty years later, on the completion of the Ordnance Survey of the kingdom. Certain anomalies in the direction of the vertical at Edinburgh led Colonel James, the director, to repeat the Schiehallion experiment, using Arthur's Seat as the deflecting mountain. The value obtained for the mean density of the earth was about $5\frac{1}{3}$.

Repetitions have also been made of the pendulum method, tried by Bouguer in the Andes.

The first of these was by Carlini, in 1821. He observed the length of a pendulum swinging seconds at the Hospice on Mont Cenis, about 6,000 feet above sea level, and so obtained the value of gravity there. The value due to mere elevation above the sea level was easily calculated ; but the observed value was greater than that calculated by about 1 in 5,000. In other words, the pull of the whole earth was 5,000 times greater than that of the mountain under the Hospice. Knowing approximately the shape of the mountain, and estimating its density from specimens of the rock, Carlini found the density of the earth to be about $4\frac{1}{2}$ times that of water.

Another experiment of the same kind was made by Mendenhall, in Japan, in 1880. Here he determined the value of gravity on the summit of Fujiyama, a mountain nearly $2\frac{1}{2}$ miles high. He found it greater than the value calculated from the increased distance from the earth's centre by about 1 in 5,000, as Carlini had done on Mont Cenis. Fujiyama, though the higher, is more pointed and less dense than Mont Cenis.

Mendenhall estimated the mean density of the earth as 5·77.

Airy applied the pendulum to solve the problem in a somewhat different way, using, instead of a mountain, the crust of the earth between the top and the bottom of a mine. His first attempts were made in 1826, at the Dolcoath copper mine, in Cornwall, which has acquired a melancholy notoriety in the last few weeks. Here he swung a pendulum first at the surface and then at the bottom of the mine. At the point below we may consider that the weight of the pendulum was due to the pull of the part of the earth within the sphere with radius reaching from the earth's centre to the point (Fig. 5.) Knowing

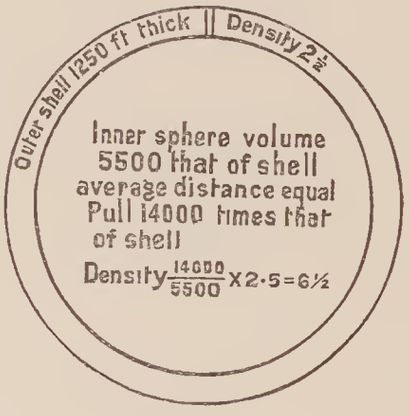

Fig. 5.

the value of gravity below, it was easy to calculate what it would have been at the level of the surface had no outer shell existed, and had the change in value depended merely on the greater distance from the earth's centre. The observed value was greater than this through the pull of the outer shell, and it was hoped that the difference would be measured sufficiently accurately to show how much greater is the mass of the earth than that of the crust. The first attempt was brought to an end by a curious accident. As one of the pendulums used was being raised up the shaft, the box containing it took fire, the rope was burnt, and the pendulum fell to the bottom. Two years later another attempt was made, but this was brought to an end by a fall in the mine, which stopped the pump so that the lower station was flooded.

Many years later, in 1854, the experiment was again undertaken by Airy, this time in the Harton coal pit, near

Sunderland. The method was exactly the same, a pendulum being swung above and below the surface, and the diminution in gravity above carefully determined. The experiment was carried out with the greatest care and in a most thorough way, two pendulums being swung at the same time—one above and one below—the two being interchanged from time to time. A small army of assistants was occupied in taking the observations, which extended continuously night and day for about three weeks. Now gravity at the surface was greater than it would have been, had no outer shell existed of thickness equal to the depth of the pit, by about 1 in 14,000, so that the pull of the earth was about 14,000 times that of the shell. The density of the shell was determined from specimens of the rocks, and Airy found the density of the earth about $6\frac{1}{2}$.

Some very interesting experiments have recently been made in a similar way by Von Sterneck in silver mines in Saxony and Bohemia. I cannot enter into details of his method, but with regard to his results I may say that he obtained different results with different depths of mines, the value of the mean density increasing with the increasing thickness of the shell used. This shows very evidently that there were sources of disturbance vitiating the method. Von Sterneck found, on comparing his observations at the two mines, that the increase in gravity on descending was much more nearly in proportion to the rise of temperature than to the depth of descent. This appears to indicate that whatever disturbs the regularity of gravity disturbs also the slope of temperature.

All the methods which I have so far described use, as you will have noticed, natural masses to compare the earth with, and herein lies a fatal defect as regards exactness. We do not know accurately the density of these masses and what is the condition of the surrounding and underlying strata. We can really only form at the best rough guesses. Indeed, the experiments might rather be turned the other way about, and assuming the value of the mean density of the earth, we might

measure the mean density of the mountain or strata of which the attraction is measured.

One, the most recently published experiment, is perhaps to be classed with those I have described, but it avoids, at any rate. this fault. It has only just been completed by M. Berget, at Habay la Neuve, in Luxembourg. He uses a lake of 79 acres area, of which he can vary the depth, and I may perhaps give you a correct notion of his method if I say that in principle he finds the variation in weight by means of a particular kind of spring balance, of a column of mercury, placed above the lake, when the lake is full and when it is lowered about a yard. He performs, in fact, Bouguer's original experiment at Quito, but under the attracted body is an artificial plateau of water, which he can place there or remove at will, instead of the natural plateau on which Quito stands. He obtained for the value of the mean density, 5·41.

We turn now to a different class of experiment, in which the attracting body is altogether on a smaller scale, so that it can be handled in the laboratory. The smallness of the attraction is compensated for by the accuracy with which we know the size and mass of the attracting body.

The idea of such an experiment is due to the Rev. John Michell, a physicist who lived in the last century. He proposed to hang up a light wooden horizontal rod by a fine wire, the rod having two small lead balls at the two ends. The rod would be twisted round if a small force were applied to either ball, until the twist of the wire neutralised the turning power of the applied force. By making the wire thin enough the rod would turn appreciably with very minute force. This constitutes what is now called a torsion balance. If a large lead sphere was brought near to one of the balls on one side of it, it would attract it, and twist the rod round. Now, if the time of vibration of such a rod to and fro when disturbed is observed, it is possible to calculate the force applied at one end corresponding to any observed twist. By bringing two spheres up, one on one side at one end and the other on the other side

at the other end, and noting the position of the rod, and then moving the spheres each to the other side of the rod, and noting its new position, it is easy to see that the change in position is four times that due to one mass alone brought up to one side of the rod.

Michell only prepared the apparatus, and did not actually use it. After his death it came into the possession of Cavendish, who modified and partly re-made it, and in the years 1797-8 carried out the celebrated experiment which bears his name.

The method of working was exactly that proposed by Michell (Fig. 6). Two small lead balls hung from the end of a light wooden

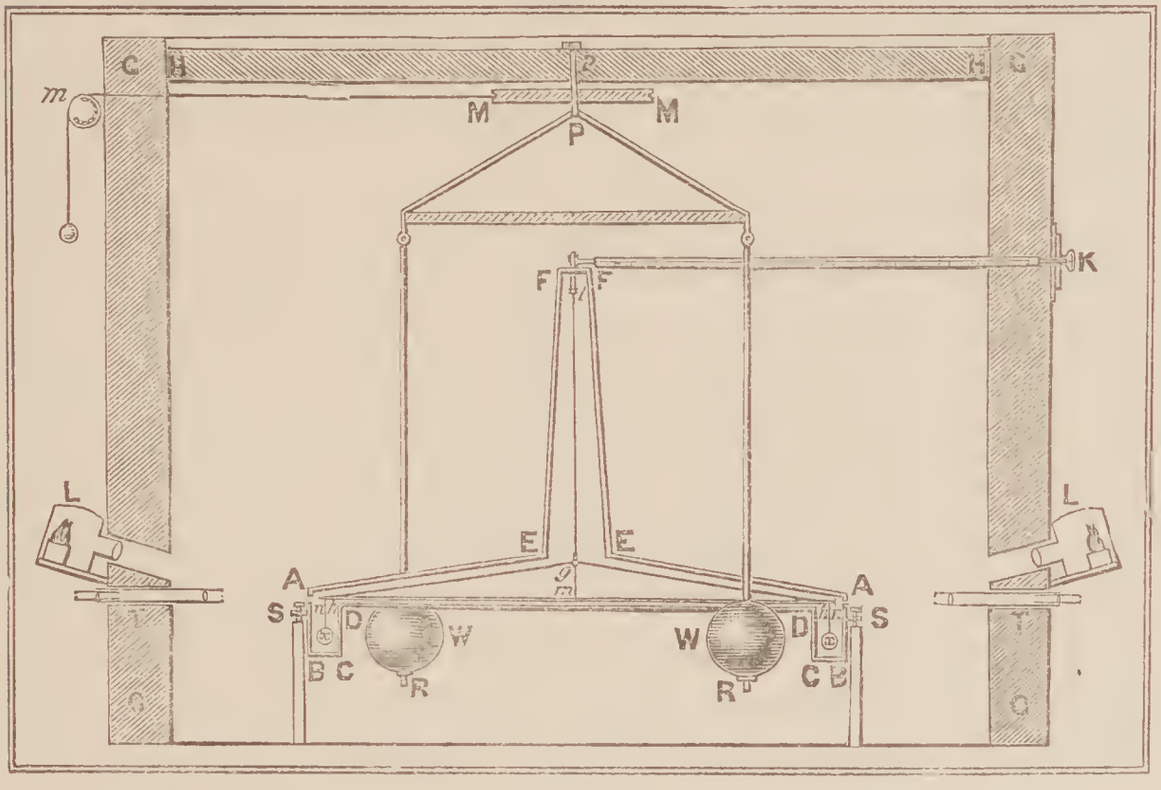

Fig. 6.

Cavendish's Apparatus.

h h, torsion rod. *x x*, balls hung from its ends. W W, attracting masses movable round axis P. T T, telescopes to view position of torsion rod.

rod suspended horizontally by a long thin wire attached to the centre of the rod. The whole was enclosed in a case. Two large lead spheres were brought up outside the case, so that they acted in opposite directions on the balls, and both tended to twist the rod the same way. They were then moved round so as to produce an opposite twist, and the total twist was

measured by a telescope viewing a scale on the rod. The time of vibration was observed, and so it was possible to calculate the attraction of the spheres on the balls, and compare it with their weight or the attraction of the earth. Thus the mass, and therefore the density, of the earth, could be found. The force of attraction of a sphere on a ball was only about $\frac{1}{4000}$ of a grain, so small a quantity that (as you may easily imagine) it was necessary to adopt most careful means to ward off draughts—not merely the coarse draughts such as exist in a room, but the minute and slow currents of air created inside the case by very minute differences of temperature. These minute currents are the great enemy in all measurements of small forces. Cavendish, nevertheless, was fairly successful in preventing them, and obtained a result of 5·448 for the mean density of the earth, a result which deserved far more confidence than any as yet obtained by the "Natural Mass" method.

His experiment has since been repeated several times. Reich made two experiments in Germany by Cavendish's method, obtaining in 1837 a value 5·49, and about 1849 a value 5·58. In England it was repeated by Baily about 1841 and 1842. Baily's experiment excited great attention at the time, and the result obtained, 5·674, was long supposed to be very near indeed to the truth. But certain discrepancies in the work gradually impaired confidence in the final result, and in 1870 MM. Comu and Baille, in France, undertook a repetition, with various improvements and refinements. In planning out their own work they succeeded in detecting probably the chief source of error in Baily's work. They are still, I believe, engaged in the experiment, and though they have given an interim result of about 5·5, and have shown that Baily's work, if properly interpreted, should bring out a not very different result, their final conclusion is still to be published.

Meanwhile, Professor Boys, in England, has taken up the experiment, striking out a new line, using for the suspending wire a thread of quartz, which, as he has discovered, possesses

splendid qualities for the work. He has shown that, without impairing its sensitiveness, the apparatus may be greatly reduced in size, and so made less liable to disturbances by air currents. He is now carrying on the experiment at Oxford, and with his brilliant skill as an experimenter, and with such well-devised apparatus, we may hope for a degree of accuracy in the result which no one supposed possible a few years ago.

About 1886, Dr. Wilsing, of Potsdam, devised a modified form of Cavendish's experiment, in which a sort of double pendulum is used, *i.e.*, one with a ball below and another at a nearly equal distance above the suspension. The pendulum is then in a very sensitive state, and a very small horizontal force pulls it through a large angle.

It is then just like a torsion balance, but with a vertical instead of a horizontal rod. If weights are brought up, one to pull the upper ball to one side and the other to pull the lower ball to the other side, the pendulum twists round slightly. From the observed twist and the time of swing the attraction can be measured and compared with the pull of the earth. Wilsing found that the earth had a mean density of 5·579.

About fifteen years ago the idea occurred nearly at the same time to the late Prof. v. Jolly and myself to apply the common balance to the problem, though in somewhat different ways. He had a balance fixed at the top of a tower in Munich, and from the scale pans hung wires supporting two other scale pans at the bottom of the tower. Imagine that two weights are balanced against each other at the top of the tower. If one is now brought down and put in the lower scale pan on the same side it is nearer the centre of the earth, and, therefore, heavier. Von Jolly found a gain of about 32 milligrams in 5 kilograms. He now built up a large lead sphere under the lower pan, a yard in diameter, so that its attraction was added to that of the earth. The gain on transferring the weight from the upper to the lower pan now came out about half a milligram more, so that the attraction of the sphere was this half milligram. The earth's

attraction was about 10,000,000 times that of the sphere, and its density was calculated to be 5·69.

An experiment very much on this principle, but with great improvements in arrangement, is now being carried out by Drs. Richarz and Krigar-Menzel, at Spandau, near Berlin. Their balance is working with such delicacy that it shows that a change in height of $2\frac{1}{2}$ yards produces less difference in a weight than it should by about one in 25,000,000 parts of the weight, probably because the upper part of the building tends to pull the weight upwards.

My own method will be seen from Fig. 7. A B are

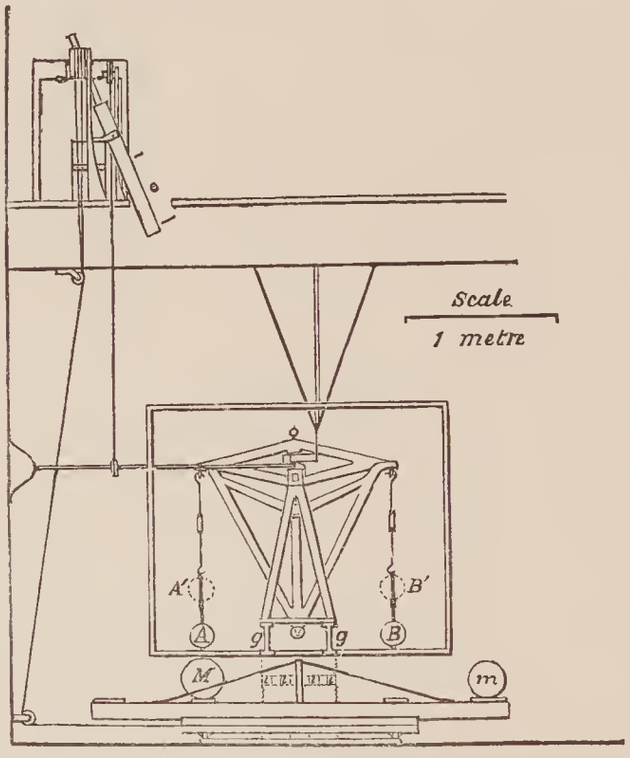

Fig. 7.

A A, weights, each about 50lbs., hanging from the two arms of balance. M, attracting mass on turn-table, movable so as to come under either A or B. *m*, balancing mass. A' B', second positions for A and B. In this position the attraction of M on the beam, and suspending wires is the same as before, so that the difference of attraction on A and B in the two positions is due to the difference in distance of A and B only, and thus the attraction on the beam, &c., is eliminated.

two lead weights, about 50lbs. each, hanging down from the ends of a very large and strong balance, inside a protecting wood case. M is a large lead sphere, weighing about 350lbs., on a turn-table so that it can move round from under A till it comes under B. The distance between the centres of

M and A or M and B is about one foot. When under A, M pulls A, and so increases its weight. When moved so as to come under B the increase is taken from A and put on to B. The balance is free to move all the time, so that it tilts over to the B side an amount due to double the attraction of M on either.

To observe the tilt, a mirror is connected with the balance so that it turns round when the balance tilts, but by the double suspension method, due to Lord Kelvin, the mirror goes through 150 times as great an angle as the balance. In the room above is a telescope, which views the reflection of a scale in the mirror, and as the mirror turns round the scale moves across the field of view. I may say that the tilt observed meant that the beam turned through rather more than 1″, and that the weight moved nearer to the mass by about $\frac{1}{8000}$ of an inch. The weight in milligrams producing this tilt had to be found. This was done virtually (though not exactly in detail) by moving a centigramme rider ($\frac{1}{6}$ of a grain) about 1 inch along the beam, which was equivalent to adding to one side a weight of about $\frac{4}{10}$ milligram ($\frac{1}{160}$ grain). The tilt due to the transfer was observed, and was found to be very nearly the same as that due to the attraction, so that the effect of moving M round from A to B was equivalent to increasing B by $\frac{4}{10}$ milligram, or $\frac{1}{50000000}$ of its previous weight. The pull on either is half this. In other words, the earth pulled either about 100,000,000 times as much as the mass M, and the earth, which is 20,000,000 times as far away, would, at the same distance, have exerted 400,000,000,000,000 times 100,000,000 times the pull, and is, therefore, so many times heavier. Thus we find that the earth weighs about 125 followed by twenty-three 0's lbs. I need not here enter into detail as to a differential method adopted to eliminate the pull of M on the beam. Perhaps fig. 7 will explain it.

To make the balance work at all exactly various precautions had to be adopted, especially to ward off disturbing air currents. It was placed in a closed cellar, and observed from the room

above through a small hole in the floor. There were other sources of error which I discovered in the course of the work, some of them leading to delays of years. One of the most serious was due to the attachment of the apparatus used to move the riders to the case containing the balance. I found that when this was used the whole case moved, and that it did not quite return to its original position. Ultimately the rider-moving apparatus had to be quite independent of the case. Then vibration from traffic in the street, or walking in the building, made the mirror quiver, so that I could not see the scale clearly. This was cured by mounting the balance on big blocks of indiarubber, so that while the supports and the case, weighing perhaps a ton, could be made to rock almost with a touch, the indiarubber absorbed all vibration coming from the floor and placed the balance beyond the reach of outside disturbances.

Once I supposed that the apparatus was in working order, and during one year I obtained a series of results. But some curious inconsistencies appeared in these, and at last I found that they were due to a tilting of the floor of the cellar when the large mass M was moved from one side to the other of the balance. The tilt was certainly small—perhaps $\frac{1}{3}''$, or say such that in a floor 10 miles long it would amount to 1 inch, yet it was quite enough to very seriously alter the result. I had long before looked for such a tilt, and thought I had proved its non-existence. But it at length asserted its existence, and in the most inconvenient way. If it had only kept the same it would probably, from the differential character of the experiment, have been nearly eliminated from the result. But it gradually grew as time went on, and the floor settled and tilted over more in one piece, and succeeded in making a year's work valueless.

In order to prevent any tilt, a second mass m was introduced of half the weight, and at double the distance. This, of course, complicated the calculation a little, but it quite cured the tilting.

While the apparatus was undergoing the changes necessary

for the introduction of the second mass, I discovered another source of error, due to an unsuspected steel core in the inside of the brass wire rope used to pull the turn-table round. This core got slightly magnetised by the earth, and exerted an attraction on the steel knife-edges of the balance, varying with its position. The brass wire was replaced by a gut rope, and the magnetic effect disappeared.

One of the most curious experiences I had occurred one day when I found the balance behaving in a most jerky and irregular way. On going downstairs and opening the case, I discovered some long white hair-like processes, perhaps $\frac{1}{2}''$ or $\frac{3}{4}''$ long, issuing from the little pegs which were used to move the riders on to or off the beam of the balance. These were of wood, covered with gold leaf, and attached to brass holders. The gold leaf had been pasted on. The paste absorbed moisture from the air, and then formed a small galvanic battery with the brass and gold leaf. Hair-like crystals, most likely of sulphate of zinc, were formed, and these grew so long that they touched the balance and interfered with its action.

Ultimately, however, all the most obvious sources of error were detected and stopped, and the balance gave, I think, a fairly good result of 5·493.

It may be interesting to state the accuracy with which it worked. The increase in the weight of the 50lbs. which was to be measured was about $\frac{1}{50000000}$ of the whole. Measurements of this increase were never wrong by more than 2 per cent. of the amount, usually well within 1 per cent., or $\frac{1}{5000000000}$ of the whole weight, the variation which would occur if the 50lbs. were moved $\frac{1}{40}$ inch nearer to the centre of the earth. Now these numbers are too large to give us much idea of the smallness of the weights concerned. Suppose, then, we take a rough illustration, in which the small weights are magnified up to be appreciable.

Imagine a balance large enough to contain on one pan the whole population of the British Islands, and that all the

population were placed there but one medium-sized boy. Then the increase in weight which had to be measured was equivalent to measuring the increase due to putting that boy on with the rest. The accuracy of measurement was equivalent to observing from the increase in weight whether or no he had taken off one of his boots before stepping on to the pan.

One of the most curious points about this method of weighing the earth is the contrast between the mass to be weighed and the mass in terms of which it is weighed. You will remember that the tilt of the balance is measured by moving a centigramme rider along the beam. Any inaccuracy in the estimation of the weight of that rider is repeated in the weight of the earth. So that in one sense we may be said to weigh the earth with its twelve billion billion pounds by using a weight of $\frac{1}{50000}$ part of a pound.

At last my long catalogue of experiments is brought to an end, or rather it is brought up to the present time, for such researches have no end. Each generation will try to add another decimal place to the result, or find out the errors of its predecessors. And even now there are many workers in the field, indeed, there is almost an epidemic of earth weighing. Besides the experiments I have already referred to as now going on, I know of at least two others not yet publicly announced.

But in a research like this, where the result is of such great interest in helping us to a knowledge of the constitution of the earth, and where all sorts of errors lie in wait to deceive the worker, there is every advantage in frequent repetition by different methods. At first the results varied a good deal, but now I think they are tending towards a steady mean. If we take the average of Newton's guess, that the mass of the earth is five or six times that of an equal globe of water, and say that it is $5\frac{1}{2}$ times that mass, I believe that we shall be correct within a very small fraction of the whole.

List of Experiments with the Results obtained.

DATE.	EXPERIMENTER.	RESULT.
1737-40	Bouguer	Inconclusive
1774-6	Maskelyne and Hutton ..	4·5 to 5
1797-8	Cavendish	5·45
1821	Carlini	4·7 about
1837	Reich	5·49
1840-1	Baily	5·674
1852	Reich	5·583
1854	Airy	6·565
1855	James and Clarke ..	5·376
1870—	Cornu and Baille ..	5·50-5·56
1879-80	Von Jolly	5·692
1883	Von Sterneck	5·77
1885	Von Sterneck	7 about
1886-8	Wilsing	5·579
1890	Poynting	5·493
1893	Berget	5·41
In progress	Cornu and Baille König, Richarz and Krigar-Menzel Boys Laska ?	

II.—*On the Decomposition of Liquids by Contact with Powdered Silica, &c.*

By Dr. G. Gore, F.R.S.

It is recorded that dilute vinegar is to some extent deprived of its acid by filtration through pure quartz sand (Gmelin's Handbook of Chemistry, Vol. I., p. 114). I have tested this statement by allowing pure very dilute acetic acid to filter at a rate of about two drops per minute through a narrow column, nine inches high, of very fine white sand, which had been washed with distilled water, digested with hot and pure hydrochloric acid, washed again, ignited, digested with pure and strong acetic acid, washed again, and heated to redness. The first portions of liquid which passed through were quite neutral to litmus paper.

It is also stated that permanganate of potassium is removed from its aqueous solution by trickling through finely divided silica. (J. J. Thomson, "Applications of Dynamics to Physics," p. 192). I repeated this experiment in a similar manner to the above, but the effect was extremely small, and complete precautions had to be taken to exclude all organic matter and dust, a mere trace of which would have been sufficient to produce the observed effect.

By similarly filtering a dilute solution of mixed sodium-potassium cyanide through the properly prepared pure sand, or by merely shaking the solution and sand together in a bottle and allowing the sand to settle, on analysing the clear liquid in each instance, it was found to contain less cyanide than the original solution. I further found that pure precipitated silica, previously ignited, abstracted a very much larger proportion of cyanide from a solution of that salt by agitation with it in a bottle, than an equal weight of the finest sand.

In this research a number of liquids were examined, and those selected were in every case such as are usually considered not to chemically act upon or combine with the powder; and in every instance with silica the process of purifying the powder included digestion of it with the particular liquid which was to be absorbed, and repeated washing, &c., as above described. In certain cases the clear supernatant liquid, after filtration, was carefully tested for dissolved silica. In every instance chemical analyses were made of each strength of solution employed before and after the contact of the liquid with the powder, and in some cases these analyses were repeated. The quantities of substance stated were in all cases those of the anhydrous bodies.

In each of the following series of experiments the required amount of soluble substance was taken, and sufficient distilled water added to it to make a total of twenty-five cubic centims. Fifty grains of the suitably prepared pure precipitated silica were then added, and the mixture well shaken in a stoppered glass bottle, then allowed to settle usually during sixteen to twenty hours, and the supernatant liquid filtered and analysed. In every instance the liquid expelled air from the silica. The substances employed (except chromic acid and potassium chlorate and cyanide), were of a high degree of purity, and in nearly all cases had been analytically examined beforehand. It was found by experience that the abstraction of the dissolved substance by agitation with the silica was completed in less than four hours. (See No. "117," also "Influence of Time.")

Experiments with Silica.

Solution No.	Per cent.	Grains.	Per cent.	Notes.
1	·25 HCl lost	·008 =	·89	Each solution was volumetrically analysed with argentic nitrate. No. "3" was repeated, and the same result was obtained. No silica was dissolved by the 10 per cent. solution in sixteen hours.
2	1·00 ,,	·25 =	6·63	
3	5·00 ,,	·35 =	1·82	
4	10·00 ,,	1·11 =	2·88	
5	10·0 HBr lost	1·04 =	2·7	The acid was colourless and was volumetrically analysed with Na^2CO^3.
6	10·0 HI lost	·387 =	1·0	Acid colourless and pure. Agitation with pure SiO^2 made it slightly red. Analysed as in No. "1."
7	1·0 H^2SO^4 no effect			Analysed as in No. "5." Repeated No. "8," and obtained similar results.
8	5·0 ,, lost	1·34 =	6·93	
9	10·0 ,, no effect			
10	10·0 CrO^3 no effect			Volumetrically analysed with ferrous sulphate.
11	1·0 HNO^3 no effect			Analysed as in No. "5." Repeated No. "11," and obtained similar results.
12	5·0 ,, lost	·35 =	1·83	
13	10·0 ,, ,,	·96 =	2·50	
14	10·0 $HClO^3$ lost	·44 =	1·16	The acid contained a trace of HCl. Analysed as in No. "5."

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
15	1·0 $HClO^4$	no effect		Acid colourless, contained a trace of $HClO^3$. Analysed as in No. "5."
16	10·0 ,,	lost ·71	= 4·43	
17	10·0 HIO^3	lost ·89	= 2·3	Acid remained colourless after the trial. Analysed as in No. "5."
18	1·0 H^3PO^4	no effect		Analysed as in No. "5."
19	10·0 ,,	lost ·63	= 6·65	
20	1·0 $H^4P^2O^7$	gain ·05	= 1·32	Analysed as in No. "5."
21	10·0 ,,	lost 2·63	= 6·8	
22	5·0 Oxalic Acid	no effect		Analysed as in No. "5."
23	10·0 Tartaric Acid	lost ·55	= 1·42	Analysed as in No. "5."
24	10·0 Citric Acid	no effect		Analysed as in No. "5."
25	5·0 Succinic Acid	lost ·53	= 2·75	Analysed as in No. "5."
26	1·0 $CuCl^2$	gain ·123	= 3·19	Analysed as in No. "1."
27	10·0 ,, ,,	·86	= 2·24	
28	10·0 $CuSO^4$	lost ·72	= 1·88	The amount of copper was found by precipitation as oxide.

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
29	10·0 $NiCl^2$ no effect			Analysed as in No. "1."
30	10·0 $NiSO^4$ no effect			The amount of salt was found by evaporation to dryness to a constant weight.
31	10·0 $CoCl^2$ lost	·92	= 2·4	Analysed as in No. "1."
32	10·0 $CoSO^4$ gained	·21	= ·56	The two solutions were analysed as in No. "30."
33	10·0 $FeCl^2$ no effect			Analysed as in No. "1."
34	10·0 $FeSO^4$ lost	1·23	= 3·2	Analysed volumetrically with $KMnO^4$.
35	10·0 $MnCl^2$ gained	·42	= 1·1	Analysed as in No. "1."
36	10·0 $MnSO^4$ gained	·39	= 1·03	Precipitated and weighed as MnO.
37	1·0 $CdCl^2$ lost	·069	= 1·8	Analysed as in No. "1."
38	5·0 ,, no effect			
39	10·0 ,, lost	·42	= 1·1	
40	10·0 $CdSO^4$ gained	·51	= 1·3	Analysed as in No. "30."

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
41	1·0 $ZnCl^2$	lost ·25	= 6·52	Analysed as in No. "1."
42	5·0 ,,	,, 1·45	= 7·50	
43	10·0 ,,	,, ·89	= 2·32	
44	1·0 $ZnSO^4$	no effect		Precipitated by $BaCl^2$ and weighed as barium sulphate.
45	10·0 ,,	gained 1·21	= 3·15	The zinc was precipitated as carbonate, ignited, and weighed.
46	1·0 $MgCl^2$	lost ·081	= 2·1	Analysed as in No. "1."
47	5·0 ,,	,, 1·33	= 6·9	
48	10·0 ,,	,, 1·00	= 2·6	
49	10·0 $MgSO^4$	gained ·91	= 2·35	The amounts of salt were found as in No. "30."
50	1·0 $CaCl^2$	lost ·158	= 4·1	Analysed as in No. "1."
51	5·0 ,,	·42	= 2·17	
52	10·0 ,,	1·19	= 3·1	
53	1·0 $SrCl^2$	lost ·13	= 3·4	Analysed as in No. "1."
54	5·0 ,,	no effect		
55	10·0 ,,	lost ·85	= 2·2	
56	10·0 $BaCl^2$	lost ·42	= 1·09	Analysed as in No. "1."
57	1·0 LCl	no effect		Analysed as in No. "1."
58	5·0 ,,	,,		
59	10·0 ,,	lost ·51	= 1·33	

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
60	·1 NaCl	no effect		Analysed as in No. "1."
61	·25 ,,	lost ·052 =	5·45	
62	1·0 ,,	,, ·077 =	2·0	
63	5·0 ,,	no effect		
64	10·0 ,,	lost 1·07 =	2·77	The 10·0 per cent liquid contained no dissolved silica after the trial.
65	1·0 NaBr	no effect		Analysed as in No. "1."
66	5·0 ,,	lost ·33 =	1·7	
67	10·0 ,,	,, ·46 =	1·2	
68	1·0 NaI	no effect		Analysed as in No. "1."
69	5·0 ,,	,,		
70	10·0 ,,	lost ·81 =	2·1	
71	10·0 Na^2SO^4	gained ·42 =	1·09	Estimated as in No. "44."
72	5·0 Na^2HPO^4	lost ·44 =	2·3	Analysed gravimetrically by means of $MgSO^4$.
73	3·0 $Na^2B^4O^7$	no effect		Examined as in No. "30."
74	·1 $NaHCO^3$	lost ·03 =	7·8	Analysed volumetrically by means of H^2SO^4. No silica was dissolved by the 10·0 per cent. solution.
75	·25 ,,	,, ·042 =	4·34	
76	1·0 ,,	,, ·101 =	2·63	
77	5·0 ,,	,, ·54 =	2·83	
78	10·0 ,,	,, ·89 =	2·30	

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
79	·025 Na^2CO^3	lost ·08	= 83·4	Tested approximately by means of test paper and comparison solution.
80	·1 ,, ,,	·144	= 37·6	Analysed as in No. "76."
81	1·0 ,, ,,	·77	= 20·0	
82	10·0 ,, ,,	1·16	= 3·0	No silica was dissolved.
83	·025 NaCy	lost ·083	= 86·7	Examined as in No. "79." The solutions were made by adding Na to aqueous HCy.
84	·1 ,, ,,	·064	= 16·6	Analysed as in No. "1."
85	1·0 ,, ,,	·59	= 15·4	
86	10·0 ,, ,,	1·27	= 3·3	No silica was dissolved by the 10·0 per cent. solution.
87	·1 KCl	lost ·0077	= 2·0	Analysed as in No. "1."
88	·25 ,,	no effect		
89	1·0 ,, ,,	·14	= 3·65	
90	5·0 ,, ,,	·178	= ·92	
91	10·0 ,,	no effect		
92	1·0 KBr	lost ·166	= 4·3	Analysed as in No. "1."
93	5·0 ,, ,,	·95	= 4·93	
94	10·0 ,, ,,	·72	= 1·87	No silica was dissolved by the 10·0 per cent. solution.
95	1·0 KI	no effect		Analysed as in No. "1."
96	5·0 ,,	lost ·77	= 4·0	
97	10·0 ,, ,,	·46	= 1·2	No silica was dissolved by this solution.

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
98	5·0 KIO^3	gained 1·22	= 6·34	Analysed by means of Sodic Hyposulphite
99	5·0 $KClO^3$	gained ·079	= ·41	Analysed by means of $FeSO^4$ and $KMnO^4$.
100	5·0 KNO^3	no effect		Analysed by weighing as dry sulphate. No silica was dissolved.
101	10·0 ,,	lost 1·47	= 3·82	
102	1·0 $KHSO^4$	lost ·338	= 8·75	Analysed as in No. "5." No silica was dissolved during six days by this solution.
103	5·0 ,,	,, ·89	= 4·6	
104	10·0 ,,	no effect		
105	10·0 K^2SO^4	gained ·32	= ·84	Analysed as in No. "44."
106	1·0 $KHCO^3$	lost ·39	= 10·2	Analysed as in No. "76."
107	10·0 ,,	,, ·44	= 1·16	
108	·025 K^2CO^3	lost ·08	= 83·4	Examined as in No. "79."
109	·10 ,,	,, ·139	= 36·1	Analysed as in No. "76." No silica was dissolved by this solution. No silica was dissolved by this solution.
110	·25 ,,	,, ·396	= 34·0	
111	1·0 ,,	,, 1·02	= 26·6	
112	5·0 ,,	,, 2·51	= 13·0	
113	10·0 ,,	,, 3·12	= 8·05	

Experiments with Silica (continued).

Solution No.	Per cent.		Grains.	Per cent.	Notes.
114	·025	KCy lost	·084	= 87·5	Tested as in No. "79."
115	·25	,, ,,	·47	= 49·0	Analysed as in No. "85." Silica digested only four hours. No difference was found either in Nos. "117" or in "118" after digestion during 16 more hours.
116	1·0	,, ,,	1·00	= 26·0	
117	5·0	,, ,,	1·88	= 9·75	
118	10·0	,, ,,	·99	= 2·56	
119	10·0	RbCl lost	·93	= 2·4	Analysed as in No. "1."
120	10·0	RbBr no effect			Analysed as in No. "1."
121	10·0	RbI lost	·89	= 2·3	Analysed as in No. "1."
122	10·0	Rb^2SO^4 lost	1·08	= 2·8	Analysed as in No. "30."
123	1·0	AmCl lost	·112	= 2·9	Analysed as in No. "1."
124	5·0	,, ,,	·70	= 3·63	
125	10·0	,, ,,	·89	= 2·32	
126	1·0	AmBr no effect			Analysed as in No. "1."
127	5·0	,, ,,			
128	10·0	,, lost	·42	= 1·1	
129	10·0	Am^2SO^4 lost	·39	= 1·01	Analysed as in No. "44."
130	·005	Am Sesquicarb lost	·0057	= 60·0	Analysed by means of Nessler's colour test.
131	·025	,, ,,	·043	= 45·0	
132	·1	,, ,,	·095	= 24·8	Analysed as in No. "76."
133	1·0	,, ,,	·309	= 8·0	
134	10·0	,, ,,	·96	= 2·5	

Experiments with Silica (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
135	1·0 AmHO	lost ·8	=20·9	Analysed as in No. "76."
136	5·0 ,,	,, 1·47	= 7·6	
137	10·0 ,,	,, 2·62	= 6·8	
138	10·0 Trimethylamine	lost 1·05	= 2·72	Determined as in No. "76."
139	·002 Iodine	lost ·00295	=38·0	Found by colour test with H^2SO^3 and starch. The silica was digested during eighteen hours.
140	·02 ,, ,,	·0209	=27·1	

On examining these results we find that by mere contact with the silica the *adhering* portion of the solution became stronger in ninety-seven instances, weaker in thirteen, and its strength was not perceptibly changed in the remaining thirty. The second group of cases may be regarded as those in which the silica united more strongly with the water than with the dissolved substance; and the third group may be considered either as those in which the amounts of dissolved substance or of water abstracted by the silica were too small to be detected by the method employed; or, more probable, that the two constituents of the liquid were abstracted in about the same proportion as they existed in the original solution. In all the various cases of alkaline solutions the *proportion* of dissolved substance abstracted was larger the greater the degree of dilution of the liquid.

We may regard the surface film of the liquid as being simply enlarged to a great extent by contact with the powder, and its solvent power being thereby usually increased, in which case the general results agree with a statement made by

J. J. Thomson that, with saline solutions, in some cases the surface film of the liquid contains more and in others less salt per unit of volume than the interior ("Applications of Dynamics to Physics," p. 191); other circumstances, however, greatly affect the results. According to this view, in ninety-seven out of 140 instances the dissolved substance was more soluble in the capillary film than in the remaining mass of liquid.

Influence of Mixed Salts.

Water was added to 50 grains of silica, 38·75 of $MgCl^2$ and 38·75 of Na^2SO^4 until a total volume of 25·0 centims of solution was attained. By means of volumetric analysis of the chlorine and gravimetric of the sulphuric acid, it was found that whilst in No. 48 a 10 per cent. solution of $MgCl^2$ alone gave a loss of 1·0 grain, or 2·6 per cent, in the present case there was no effect; and whilst a 10 per cent. solution of Na^2SO^4 alone gave a gain of ·42 grains, or 1·09 per cent. (see No. "71"), in the present instance there was a loss of 1·05 grains, or 2·8 per cent. With a solution containing 10 per cent. *each* of KCl and K^2CO^3, analysed as in Nos. "1" and "76," after standing sixteen hours with 50 grains of silica, the KCl lost 4·68 grains = 12·17 per cent., and the K^2CO^3 lost 4·3 grains = 11·17 per cent., the loss in each case being increased by mixture (compare Nos. "91" and "113"). These results show that salts in admixture disturb each other's effect.

Comparison of Filtration with Agitation and Subsidence.

The ·025 per cent. solution of KCy was filtered through 50 grains of the silica in a column $7\frac{1}{2}$ inches high, it passed through in about $1\frac{1}{2}$ or two hours, and the first portion showed a loss of about 50·0 per cent. This was considerably less than that obtained by the ordinary method of agitation and subsidence (compare No. "114"). Shaking, therefore, appears to promote the action.

Influence of Time.

The experiment with the ·025 per cent. solution of Ammonium Sesquicarbonate (see No. "131") was repeated, the period of digestion with the silica being only two hours. The proportion of salt abstracted was apparently the same as in the former case after four hours. The ·25 per cent. solution of KCy of No. "115" was also analysed after digestion of the silica in it during four hours and after sixteen hours, and the same result obtained in each case (compare notes of Nos. "117" and "118"). The results show that prolonged digestion with the silica is unnecessary.

Influence of Strength of the Solution.

In the case of solutions which had an alkaline reaction, the actual amount of dissolved substance abstracted by the silica was nearly always greater, and the proportional amount nearly always less, the stronger the solution; but with solutions of acids or of neutral salts the effects were very variable. An inspection of the foregoing table supports these statements.

Influence of Varying the Proportion of Silica.

Whilst the 25 c.c. of 10·0 per cent. solution of potassic carbonate digested with 50 grains of silica during sixteen hours lost 3·12 grains, or 8·05 per cent. (see No. "113"), the same amount of the same solution digested with 100 grains of silica during the same period of time lost 4·16 grains or 11·11 per cent. The amount of effect increased with the proportion of the silica.

Influence of Temperature.

The 1·0 per cent. solution of potassic carbonate in contact with silica, which gave a loss of 1·02 grains = 26·6 per cent. at atmospheric temperatures (see No. "111"), lost 2·13 grains = 27·5 per cent at 140° Fahr., each after a period of four hours digestion; temperature, therefore, had but little effect. No silica was dissolved.

Influence of Kind of Solvent.

By employing a one per cent. solution of NaCy in a mixture of equal volumes of water and absolute alcohol and the usual proportion of silica, a loss of ·5 grain = 13·0 per cent. of the salt occured. This was a somewhat smaller effect than when the solvent was water alone. Compare No. "85." And by using a one per cent. solution of K^2CO^3 in a similar manner, a loss of 1·22 grain = 31·7 per cent. occurred, which was somewhat greater than with water alone as the solvent. Compare No. "111." The kind of solvent therefore has evidently an influence upon the effect.

Influence of Nascent State.

It is well known to chemical analysts that certain precipitates during their act of formation in particular liquids carry down with them by adhesion some of the soluble constituents of the liquids, and a very large amount of washing is required to remove the impurity.* In order, therefore, to test whether in such a case the precipitated powder during its freshly formed or nascent state abstracted a larger portion of the dissolved substance than when in the usual previously prepared condition, the following experiments were made:— Equivalent quantities of potassium sulphate and barium nitrate, sufficient to form 22·41 grains of potassium nitrate and 25·9 grains of barium sulphate, were dissolved in separate quantities of water to make in each case 12·5 centims of solution, and the latter solution was added to the former one in a stoppered bottle; at the same time 25·9 grains of barium sulphate were added to 25·0 centims of solution containing 22·41 grains of potassium nitrate in a second bottle. The two mixtures were then equally shaken and set aside to rest during thirty-six hours; the previously precipitated substance subsided

* In making alumina from ammonia alum and aqueous ammonia, sulphate of ammonia adhered to the precipitated alumina, even after apparently perfect washing, and was found after subsequently heating the precipitate to bright redness.

in about one-fortieth the time of the other. To equal volumes of the clear, decanted liquids were then added full equivalent quantities of sulphuric acid, and the mixtures evaporated to dryness and a constant weight of K^2SO^4. The liquid from the nascent sulphate gave a loss of 4·13 per cent., and that from the previously prepared sulphate, after correction for the volume occupied by the dry sulphate, gave a loss of 2·58 per cent. = a difference of 1·55 between the two percentages. In a repetition of this experiment, the two liquids being analysed by means of protochloride of iron and potassium permanganate. the solution with the nascent powder again suffered the greatest loss of potassium nitrate, but the difference between the two percentages in this case was 1·21 ; the former analysis was the most reliable one.

According to the results of these experiments the amount of dissolved substance abstracted from the liquid is affected by the nascent state of the powder, and the nascent substance has greater effect than the previously prepared one.

Experiments with Titanic Acid.

This powder was finer than the silica ; it was highly pure. but was was not previous washed with the electrolytes.

Solution No.	Per cent.	Grains.	Per cent.	Notes.
141	1·0 Na^2Co^3 lost	·255 =	6·6	Analysed as in No. "76," after subsiding clear in 4 hours.
142	1·0 K^2CO^3 ,,	·23 =	5·95	Analysed as in No. "76," after subsiding clear in 4 hours.
143	1·0 KCy no effect			Analysed as in No. "85." after subsiding clear in 4 hours.
144	·1 Am Sesquicarb lost ·084 =		21·8	Analysed as in No. "76," after subsiding clear in 16 hours.

Experiments with Titanic Acid (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
145	1·0 ,,	,, ·34 =	9·0	Analysed as in No. "76," after subsiding clear in 16 hours.
146	1·0AmHO	,, ·20 =	5·15	Analysed as in No. "76." Required 40 hours to perfectly subside.

The titanic acid had usually a much smaller effect than the silica.

Experiments with Stannic Oxide.

147. The oxide was very pure and a finer powder than the silica ; it was not previously washed with the electrolytes. The one per cent. solutions of sodium carbonate, potassium carbonate, potassium cyanide, ammonium sesquicarbonate, and caustic ammonia were analysed after a period of four hours, but neither of them showed any abstraction either of the salt or of the water by the oxide. The action of this oxide was feebler than that of any other of the powders examined.

Experiments with Alumina.

The alumina was the precipitated pure substance, and was treated in a similar manner to the silica. It was previously heated to redness and perfectly washed with water.

Solution No.	Per cent.	Grains.	Per cent.	Notes.
148	·02 Iodine lost	·0116 =	15·0	Analysed as in No. "140," after standing 16 hours.
149	1·0 AmCl	,, ·125 =	3·3	Analysed as in No. "1," after standing 16 hours.

Experiments with Alumina (continued).

Solution No.	Per cent.		Grains.	Per cent.	Notes.
150	10·0	,,	,, ·76 =	2·0	Analysed as in No. "1," after standing 16 hours.
151	1·0	AmBr	,, ·12 =	3·10	Analysed as in No. "1," after standing 16 hours.
152	10·0	,,	No effect		Analysed as in No. "1," after standing 16 hours.
153	·1	Am Sesquicarb	lost ·116 =	30·0	Analysed as in No. "76," after standing 16 hours.
154	1·0	,,	,, 1·01 =	26·1	Analysed as in No. "76," after standing 16 hours.
155	10·0	Am^2So^4	,, ·378 =	·98	Analysed as in No. "44," after standing 16 hours.
156	1·0	AmHO	,, ·505 =	13·1	Analysed as in No. "76," after standing 16 hours.
157	10·0	,,	No effect		Analysed as in No. "76," after standing 16 hours. With 200 grains of the powder there was also no effect.

The effects with alumina were generally less than those with silica.

Experiments with Ferric Oxide.

The oxide was very pure, but was not previously washed with the electrolytes; it subsided quickly.

Solution No.	Per cent.		Grains.	Per cent.	Notes.
158	1·0	Na^2CO^3	no effect		Analysed as in No. "76," after standing 16 hours.

Experiments with Ferric Oxide (continued).

Solution No.	Per cent.	Grains.	Per cent.	Notes.
159	1·0 K^2CO^3	lost ·131 =	3·4	Analysed as in No. "76," after standing 16 hours.
160	1·0 KCy	no effect		Analysed as in No. "85," after standing 16 hours.
161	1·0 Am Sesquicarb	lost ·174 =	4·5	Analysed as in No. "76," after standing 16 hours.
162	1·0 AmHO	no effect		Analysed as in No. "76," after standing 16 hours.

The effects were usually feebler than those obtained with alumina or silica.

Experiments with Magnesium Carbonate.

Corrections were made for the solubility of the carbonate in water.

Solution No.	Per cent.	Grains.	Per cent.	Notes.
163	1·0 Na^2CO^3	lost ·336 =	8·7	Analysed as in No. "76," after standing 16 hours.
164	1·0 K^2CO^3	,, ·51 =	13·2	Analysed as in No. "76," after standing 4 hours.
165	1·0 KCy	no effect		Analysed as in No. "85," after standing 16 hours.
166	1·0 Am Sesquicarb	lost ·178 =	4·6	Analysed as in No. "76," after standing 16 hours.
167	1·0 AmHO	,, ·203 =	5·26	Analysed as in No. "76," after standing 4 hours.

The effects were much more feeble than those obtained with silica.

Experiments with Calcium Carbonate.

168. With the usual weights of the pure precipitated carbonate, and the usual volumes of 1 per cent. solutions of the carbonates of sodium, potassium, and ammonium, potassium cyanide, and caustic ammonia, no alteration of strength of either of the liquids occurred.

Experiments with Barium Sulphate.

Solution No.	Per cent.	Grains.	Per cent.	Notes.
169	1·0 HCl	no effect		Analysed as in No. "1" after standing 16 hours.
170	1·0 NaCl	gained ·08	=2·07	Analysed as in No. "1" after standing 16 hours.
171	·5 K^2CO^3	loss of ·098	=5·10	Analysed as in No. "76" after standing 16 hours.
172	1·0 „	gained ·138	=3·59	Analysed as in No. "76" after standing 16 hours.
173	10·0 „	no effect		Analysed as in No. "76" after standing 16 hours.
174	1·0 KCy	„		Analysed as in No. "85" after standing 16 hours.

The effects were feeble in comparison with those obtained with silica.

Experiments with Mixtures of Powders.

175-176. A mixture of 25 grains of silica and 25 grains of alumina previously washed with a solution of ammonium chloride, then with water, and ignited, was shaken with 25·0 centims of a 10·0 per cent. solution containing 38·7 grains of sal ammoniac. No change of composition of the liquid occurred (compare Nos. "125" and "150"). A similar mixture of 25 grains each of silica and sulphate of barium, previously

treated with a solution of potassium carbonate, washed and ignited, was employed with 25 c.c. of a 1·0 per cent. solution of the carbonate; the solution lost ·73 grain of K^2CO^3=19·7 per cent. (compare Nos. "111" and "172"). Mixed powders like mixed solutions, appear to disturb each other's effect.

General Remarks and Conclusions.

The results of this research show clearly that the power of abstracting dissolved substances from liquids is a common property of finely divided solid bodies, and that the amount abstracted varies with the following circumstances:—1st, the kind of powder employed; 2nd, the degree of fineness of the powder, and consequently the amount of its surface; 3rd, the kind of dissolved substance; 4th, the proportion of powder to dissolved substance; 5th, the kind of solvent; 6th, the proportion of solvent to powder; 7th, the proportion of dissolved substance to solvent; and, 8th, in a small degree with the temperature. The union takes place quickly, and a longer period of time has but little influence. Finely precipitated silica possesses the property in the greatest degree, and alkaline substances are the most affected.

The fact that the amount of effect varied with the *kind* of powder, and was usually greater with silica than with other substance of equal or even greater degree of fineness, proves that it is not entirely due to increased amount of surface of the liquid in contact with the solid. The action of the powder is not limited to the dissolved substance but extends also to the solvent; this is proved by the circumstance that in some cases there is a *gain* of dissolved substance by the external mass of the liquid, indicating an abstraction of the *solvent* by the powder. The results clearly show that the action depends both upon the solid and upon the liquid; in this respect it is similar to chemical union.

The action is evidently limited to the superficial layers of molecules of the solid and liquid; the finer the powder and the larger the proportion of it to the liquid the greater usually was

the effect. The phenomenon is also an instance of molecular balance in which the equilibrium is disturbed by altering either the nature or the amount of either of the substances present. It is like that of mixing an equivalent of soda solution with an equivalent each of nitric and sulphuric acids, in which case the base divides itself between the two acids in a proportion which varies with the amount of each of the substances present; in a similar manner the dissolved substance divides itself between the powder and the solvent, and the powder divides itself between the solvent and the dissolved substance.

The action is a reversible one :—By shaking an insoluble powder with a solution of a salt or acid the former usually abstracts the salt or acid from the solvent; whilst by subsequently shaking the drained powder with the solvent the latter removes the salt or acid from the powder. These apparently contradictory effects are very similar to those obtained by passing hydrogen over red-hot oxide of iron, and then passing the resulting steam over the red-hot reduced iron; the chief difference in the two cases being that in the former case the changes are physical and feeble, whilst in the latter they are chemical and strong. The circumstance which determines the reversal is probably a change in some of the molecular velocities of the substances present.

Bearing upon the same subject, Pouillet, and subsequently Regnault and Meissner, have shown that when an insoluble non-corroded powder absorbs a liquid a minute amount of heat is evolved. ("Annales de Chemie," 1822, vol. 20, pp. 141-162. "Gmelin's Handbook of Chemistry," vol. 1, p. 300. "Nature," Nov. 4th, 1886, p. 24); and I have recently made many experiments of a similar kind, with a different class of liquids, and obtained the same general effect. As I found that heat was evolved in nearly every case, the powder probably abstracts some of the dissolved substance, the water, or both, in all cases. In this respect also, *i.e.*, the evolution of heat, the present phenomena are similar to those of chemical union.

As the portion of liquid in the pores of the powder has a somewhat different composition from the remainder of the bulk, it must also have somewhat different properties; and as the action is attended by evolution of heat, the abstracted portion of liquid has probably less energy and greater specific gravity usually than the remainder. Rücker has found that the thinner parts of a soap film have different electric conduction resistance than the thicker ones ("Nature," June 1st, 1893, p. 116).

As the action appears to be in several fundamental respects the same as that occurring in well-known cases of chemical change and equilibrium, although more feeble and more simple, it is probably determined by the same general laws and conditions, and capable of the same fundamental explanation.

A mechanical explanation I venture to offer of the phenomenon is that the molecules of the powder and of the liquid, being brought into mutual contact, a small proportion of the molecular motion of the former substance is neutralised by an equivalent proportion of that of the latter, and converted into heat, and the two sets of molecules being thus brought into nearer proximity, and having lost a portion of their motion, retain their new positions and distances. I have not ascertained by experiment whether a contraction of volume of the liquid really occurs during the action.

Although the substances do not appear to unite together in chemical equivalent proportions, the third law of motion requires that the action and reaction of the two sets of molecules must be equal, and that the phenomena must in some form include equivalent quantities of the substances and of neutralised energy. Equal weights of silica of the same degree of fineness and amount of active surface ought to abstract equivalent quantities of acid + water, salt + water, &c., the water or other solvent forming a part of the equivalent weight; all that adheres to 100 parts of silica in one case ought to be mechanically equivalent to all that adheres to it in another case.

The results appear to throw some light upon the purification of water by filtration through the earth and upon agriculture, and to show that the alkaline constituents of soils are retained much more by the silica than by the alumina. The effects of silica upon weak solutions of potassium cyanide indicate that the great loss of the latter substance in the commercial process of extracting gold and silver from powdered quartz is largely due to the "adhesion" of that salt to the silica. And the results obtained with silica and a very weak solution of iodine indicate a possible method of extracting the latter substance from solutions, and the recovery of the iodine from the silica by distillation. Additional experiments with other kinds of powder and liquids would probably yield other practical results. The research is evidently capable of further extension by the use of a greater variety and number of substances, and by the employment of mathematical methods. The general result of the research is to more closely connect together the subjects of physics and chemistry.

Additional Experiments and Remarks.

Solution No.	Grains.		Centims.	Per cent. Solution.		Grains	Per cent.	Notes.
177	100	Al^2O^3	+ 25 of	10	NaCl lost	·42	= 1·10	Analysed as in No. "1."
178	50	,,	+ 25 ,,	10	$CdSo^4$,,	·275	= ·71	Analysed as in No. "30."

In a repetition of experiment "178," employing the same weight (viz., 38·75 grains of the salt), and similar in every respect except that the alumina was simply allowed to fall in gradually and subside, without being at all shaken, exactly the same numerical results were obtained.

·179-180. A first treatment of 180 centims of a ten per cent. solution of the potassium cyanide with 360 grains of the precipitated silica, removed 7·14 grains, or 2·56 per cent. of the

salt. And a second treatment of 45 centims of the clear residuary liquid, with 90 grains of the silica, removed a further amount of 1·92 grains, or 2·69 per cent. more of the residuary cyanide. These results indicate that the degree of adhesion to the silica of the salt in the residuary solution was not widely different from that in the original liquid, and that the molecules of the former solution were not less active than those of the latter.

Although in all cases the wetting of the powder and the abstraction effect appeared to be complete immediately after the thorough shaking of the mixture, a very slight evolution of minute air-bubbles, and consequently a small extension of amount of contact surface of the liquid and solid, and the substitution of the liquid film for the air one, continued. With peroxide of iron the escape of air-bubbles ceased in about half an hour, but with silica and alumina it continued during several days. With coarse sand the air-bubbles did not at all appear.

The action occurring in all the experiments of this research is analogous to that of chemical substitution; the liquid displaces a film of air, and the powder displaces portions of the solvent and the dissolved substance from their union with each other, and unites with them instead; but being only a feeble action it does not overcome strong chemical union.

It is not improbable that the phenomenon of adhesion of solvents and dissolved substances to powders is related to that of increased strength imparted to canvas by wetting it with water ("Jour. Soc. Chem. Industry," October 31st, 1893, Vol. XII,. p. 825), and to the well-known facts that powders contract and dry ropes become shorter when wetted.

III.—*Early Iron Working in the Highlands of Scotland.*

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The Analyses by G. E. Brown.

[Read before the Society, May 24th, 1893.]

Loch Maree is one of the finest of the Scotch lochs, lying in the Parish of Gairloch, in the county of Ross. It is about 12½ miles in length and varies in breadth, being about two miles across towards the middle of its length. About the centre of the loch are several small islands. At parts the shores are well wooded, while the mountains rise up behind, Slioch on the east and Ben Eay on the west being the most prominent. On the south-western side runs a road from Slattadale to Kinlochewe, which is part of the high road from Gairloch to Auchnasheen, and affords fine views across the loch. On the eastern side there is no road, and for the greater part of the way, merely shepherd's tracks.

In the summer of 1892 an excursion into the district around Loch Maree, in company with Professor Thorpe, who

was engaged in making magnetic observations, led me to visit Kinlochewe, a well-known resort at the head of the loch.

A map of the neighbourhood made us acquainted with the fact that we were close to many of the localities in which the operation of extracting iron from the ore had been practised in times, now far remote, and we accordingly took the opportunity of visiting several of the spots thus indicated. In particular we carefully inspected the south-east extremity of the loch at the place called Fasagh in the map, where the remains of the furnaces were most clearly marked, not only by heaps of slag, but also by the semi-fused bottoms (or bears) which could easily be traced, the ground having been apparently cleared by comparatively recent excavations.

We found here several large flat slabs of malleable iron, of which we took away specimens for analysis, and a pig of cast iron about three feet in length and of triangular section, which, owing to its weight, we were reluctantly compelled to leave behind.

These products were, in all probability, left when the workings were abandoned, and hence must have been lying upon the spot where we found them for some two hundred years.

The early history of iron working in the British Isles is altogether founded upon conjecture, partly supported by tradition. There appears to be no doubt that before the invasion of the Romans (B.C. 55) iron was used and probably worked in these islands. But, doubtless, the Britons received some instruction in the difficult working of this valuable metal from the successive invaders (first the Romans and subsequently the Saxons) who found their way into this country from Europe. Doubtless, in these early times the methods of extraction were rude and wasteful. That no effort was made to obtain the whole of the iron from the ore is shown by the accumulations of slags and refuse, rich in iron, which were left by the iron-workers during the period of the Roman occupation, which

remained until, in a later age, improved methods and appliances enabled them to be worked up economically.

The following passages occur in Phillips's "Treatise on Ore Deposits" (Macmillan, 1884), page 156 :—

"That the Romans carried on the manufacture of iron on a large scale and for a lengthened period in the Forest of Dean, is sufficiently proved by coins and other relics of that people which have been found under heaps of slag which were once so abundant as to form an important proportion of the material supplied to the local iron furnaces.

"The earliest historical records respecting this district are clearly identified with its iron trade; for although the pages of the Domesday Book supply no definite information relative to this industry, they nevertheless distinctly allude to the production of iron in the immediate neighbourhood. It is there stated, however, that the bolts and bars required by the ship-builders of the Royal Navy were obtained from the city of Gloucester, and there can be little doubt that the iron was produced in the Forest of Dean. In the year 1140 the Abbey of Flaxley was founded by Roger, eldest son of the Earl of Hereford, by whom it was partially endowed, and by whom it was named the 'Abbey of St. Mary de Dene,' its site being at that time included within the precincts of the Forest. The institution of the abbey was confirmed by Henry II., who further enriched it by granting to the monks permission to feed their cattle and hogs in the Forest, to repair their buildings with its timber, and to establish iron forges within its boundaries.

"For a period of more than five centuries the iron trade established by the monks of Flaxley appears to have been carried on in almost every part of the Forest capable of furnishing the requisite ore and charcoal, and where a running stream supplied the power necessary for a blast."

Phillips, p. 172 :—

"The history of the workings of the ores from the Oolite of the Midland district is a somewhat remarkable one. There

is evidence that as long ago as the Roman occupation of the country, these beds of iron ore were extensively worked, since in a wood near Oundle, heaps of broken ore, piles of the same ore after calcination, and very large quantities of slag are found associated with the Roman coins and pottery. It is further known from existing documents that during later times Rockingham Forest vied with the Weald of Kent and Sussex as an iron-producing district. In both these areas the presence of beds of iron ore in the close proximity of an almost unlimited supply of timber had, at a very early date, led to the erection of numerous forges of the kind then employed for the manufacture of iron. Throughout nearly the whole of the Northamptonshire district large accumulations of rich iron slags are still met with. They are dark in colour, very heavy and compact, and apparently contain a large proportion of the iron originally present in the ores treated."

The primitive method in all the countries of the world for the extraction of iron seems to have been based upon the employment of charcoal as the fuel, and the introduction of lumps of the ore into the fire urged by a blast of air.

The result was a mass of spongy iron, which might assume more or less the character of steel, according to the length of time the metal had been in contact with the carbonaceous fuel. Cast iron is a product of later times, and, if produced accidentally, must have appeared to have very little connection with the iron which was workable under the hammer.

The district we visited must have been for many centuries in the state of the utmost barbarism. At a distance from Edinburgh of upwards of 200 miles, in the midst of country for the most part wild and mountainous, and incapable of cultivation, it is obvious that in the earliest times the working of iron, or any other similar industry, could only have been carried on for the purpose of supplying local needs. There are remains in many parts of the Highlands consisting of iron slag, cinders, and charcoal, which seem to show that the processes of iron-working must have been widely practised there; but the

existence of the industry attracted no attention, probably because the amount of product was small, and merely sufficed for local purposes.

In writers on the antiquity of iron in England there are frequent references to the iron-working of times antecedent to the 17th century.

Leland, for example (1506-1552), refers to the workings in the Forest of Dean; and Camden (1551-1623), to the iron mines and furnaces of Sussex.

In 1558, and, again, in 1581 (Elizabeth), Acts were passed prohibiting the felling of timber in certain districts of Kent, Surrey, and Sussex, for the purposes of providing fuel for burning iron.

It is rather singular that the works of reference relating to the history of iron manufacture make no mention of these workings in the far north. Thus I have not been able to find anything relating to the subject in "Percy's Iron and Steel." "Scrivener's History of the Iron Trade" (Longmans, 1854); "Swank's Manufacture of Iron in All Ages" (Published by the Author, 1884), "Day (St. J. V.) High Antiquity of Iron and Steel, 1873," and "Evidences as to Early Use of Iron, 1875," also make no reference to iron-making in the the Highlands; though in Swank's book there is a passage to the effect that in 1615 there were 800 furnaces or forges, in Scotland, England, Ireland, and Wales. The best account is given in a book by Mr. J. H. Dixon, F.S.A., entitled "Gairloch: Its Records, Traditions, Inhabitants, and Natural History" (Edinburgh Co-operative Printing Company, 1886), which deserves to be described as something more than a mere guide book. According to the author, the whole iron industry of Scotland sprang from the workings established early in the 17th century upon the shores of Loch Maree.

The following account is abstracted from Mr. Dixon's book, page 77 :—

"In 1598 a party of gentlemen, known as the 'Fife

Adventurers,' obtained a grant from the Crown of the Island of the Lews, and took steps to plant a colony there. Mackenzies of Kintail and the M'Leods of the Lews, ceasing for a time their own feuds, combined to oust the 'Fife Adventurers.' In 1607 the King granted the Lews to Lord Balmerino (Secretary for Scotland), Sir George Hay, and Sir Jas. Spens (one of the original 'Fife Adventurers'), who in 1608 renewed the attempt to colonize the Lews, but without success. In 1609 Lord Balmerino was convicted of high treason and executed, thus forfeiting his share. Sir George Hay and Sir Jas. Spens about that time sent an expedition to the Lews, but Neil M'Leod, secretly backed by Mackenzie of Kintail, opposed the intending colonists, who were driven from the island. Mackenzie was raised to the peerage in the same year, with the title of Lord Mackenzie of Kintail; after he induced Sir George Hay and Sir Jas. Spens to give up their scheme and transfer their rights in the Lews to himself. Lord Mackenzie in part payment gave them the woods of Letterewe for iron smelting; this arrangement was concluded in 1610, and Lord Mackenzie then obtained a fresh grant to himself from the Crown."

It appears from this and other evidence that the works on Loch Maree were begun by Sir George Hay in 1607.

Mr. Dixon's book also supplies the following facts, page 78 ("History of Sir George Hay"):—

"Sir George Hay, the founder of the industry around Loch Maree, was the second son of Peter Hay of Melginche, and was born in 1572.

"He completed his education at the Scots College at Douay in France. He was introduced at Court about 1596, and appears at once to have attracted the attention of James VI., who in 1598 gave him the Carthusian priory or charter-house at Perth, together with the ecclesiastical lands of Errol, and a seat in Parliament as a peer. But he declined the peerage, was knighted instead, and subsequently adopted the profession of the law, in which he attained to great distinction.

He seems to have been a favourite with the king, whom he defended when in 1600 an attempt on his majesty's life was made by the Earl of Gowrie. Assisted by the favour of the Crown he acquired large territories, both in the Highlands and Lowlands. But some think that he settled at Letterewe at a time when he was under a cloud. Political troubles had arisen; one of his partners, Lord Balmerino, had been convicted of high treason and executed; so that the statement that Sir George had chose the remote Letterewe "for the sake of quiet in those turbulent times" appears reasonable enough. The fact that he employed the period of his enforced exile in establishing and developing iron smelting is a standing testimony to the energy of this remarkable man. He is supposed to have resided for some years at Letterewe, or, at any rate, to have made his head-quarters there. He afterwards departed for the south, and subsequently became High Chancellor of Scotland.

"The only Gairloch iron furnaces which we can be sure were carried on by Sir George Hay were those at Letterewe, Talladale, and the Red Smiddy, at Poolewe. The vast woods of Letterewe were undoubtedly the prime motive that led Sir George to start the ironworks there. They must have been very extensive, for it is the opinion of those who should know that each furnace would annually use, as carbonised fuel, the product of one hundred and twenty acres of wood. The works Sir George conducted seem to have combined two classes of industry: (1) The manufacture of wrought iron, the ore being smelted with charcoal into a mass of metal called a bloom, which was hammered whilst yet hot into bars of wrought iron, or into various articles used in the arts of peace or war. (2) The manufacture of pig iron and articles of cast iron, the metal being poured into moulds."

That cast iron was made at the works round Loch Maree is certain, from the facts mentioned in Mr. Dixon's book, and from the existence of at least one pig of iron remaining to this

day upon the spot visited by Prof. Thorpe and myself. Whether the works at this spot were carried on by Sir George Hay is a question now unanswerable, though the close proximity of Fasagh to Letterewe, both being on the same side of the loch, and not more than about five miles apart, renders this highly probable.

I brought away also a small fragment of what appeared to have been a portion of a mould or casting pot. The material of which it is made consists of silicious iron slag mixed with carbonaceous matter.

The works at Fasagh were situated upon the south side of the burn close to where it runs into the loch, and here, as pointed out by Mr. Dixon, there are remains of a "sluice" or "dam." The tuyere of a furnace was, in 1882, removed from a cottage close by, and other relics of machinery have been discovered in the neighbourhood.

Sir George Hay died in London in 1634. The works were continued after his death, but whether they went on—according to local tradition—to the early part of the 18th century, *i.e.*, for a hundred years or more, is very doubtful. It is obvious that they could not survive the destruction of the woods which furnished them with fuel, and the existence of which must have been one strong motive for the establishment of the industry in a locality so remote and so difficult of access. To the present day there is no cart road on the east side of Loch Maree, upon which Letterewe and Fasagh are situated.

Ores Used by the Ancient Ironworkers.

The ore used by these ironworkers was probably a form of hydrated oxide of iron, known as "bog iron." It occurs in various localities, and has been probably formed by deposition from ferruginous waters under the influence of living organisms.

In the parish of Gairloch there are still quantities of "bog iron" to be seen. Many of the samples have been

analysed, and found to contain on the average about 50 per cent. of metallic iron.

No deposits of "bog iron" have been found near the remains of the ancient ironworks, probably because the ironworkers consumed all that was conveniently near to their hands. However, in the neighbourhood of all the remains of ironworks at Gairloch there are to be seen ferruginous rocks and shales, some containing as much as 8 per cent. of the metal, but others not so much. When the local supplies of ore failed, there is abundant evidence that ores were imported from the south; and from the remains found near Poolewe, Letterewe, and other localities where the smelting was carried on, the imported ores appear to have been Cumberland hematite and clay ironstone, probably obtained from the south of Scotland.

The analysis of the sample of iron found at Fasagh furnishes the following results:—*Silicon*, estimated by treatment of the iron with aqua regia—·047 per cent. *Sulphur*, present in quantity too small to estimate. *Phosphorus*, by treatment of the iron with nitric acid, precipitation with ammonium molybdate, dissolving the precipitate in ammonia, and finally precipitating the phosphorus as magnesium ammonium phosphate—·246 per cent.

A second determination of the phosphorus was made, in which the precipitate of phospho-molybdate was washed with hot water acidulated with nitric acid, the filter dried at 100°, and the precipitate brushed out on to a watch glass and weighed. The percentage of phosphorus obtained by this method was ·249.

The *Manganese* was estimated by the usual process of solution of the metal in aqua regia, and the subsequent removal of the iron from the neutralised solution by the addition of ammonium acetate. The precipitated iron was dissolved in dilute hydrochloric acid, and again precipitated. The manganese from the two filtrates was precipitated by digestion with bromine, and subsequent addition of ammonia. This process gave a percentage of ·08 Mn.

The *total* carbon, estimated by solution of the iron in sodio-cupric chloride and combustion of the residue, amounted to ·140 per cent. The graphitic carbon, estimated by solution of the iron in dilute hydrochloric acid, and combustion of the residue, gave a percentage of ·12.

The combined carbon was estimated by the colour test of Eggertz. In a sample bored from the surface of the metal it amounted to ·045, whilst a second estimation on a sample bored from the centre of the piece resulted in a percentage of ·063 of combined carbon.

The results of these analyses are tabulated below:—

Silicon	·047 per cent.
Phosphorus	·247 ,,
Manganese	·08 ,,
Total carbon	·14.
(Graphitic carbon, ·12).	

The bar iron from Fasagh appears to consist of nearly pure malleable iron, containing streaks and layers of steely iron. When the slab was bored into with a drill it was found that the surface generally was softer than some deeper portions, but the whole may readily be forged into a bar which exhibits no appreciable brittleness, and is easily worked by the file. This iron is, therefore, similar to the charcoal iron which to this day is made in small bloomeries in India and in some places in the Pyrenees. It also somewhat resembles the "puddled steel" which is manufactured in this country to some extent for making agricultural implements and other purposes. The chief difference is in the very small proportion of manganese present in the specimen from Loch Maree.

P.S.—November, 1893.—Since this paper was communicated to the Society, I have become aware of a much more complete and exhaustive historical account of the ancient iron industry of Scotland in a paper by Dr. W. Ivison Macadam, F.I.C., in the third volume of the "Transactions of the Inverness Scientific Society and Field Club."

W. A. T.

IV.—*The Morphology of the Sensory Canal System in Some Fossil Fishes.*

By Walter E. Collinge,
Demonstrator of Biology, Mason College, Birmingham.

[Read before the Society on October 19th, 1893.]

Whilst I have been working upon the Sensory Canal System in recent fishes it occurred to me that it would be interesting to learn what evidence there was of this system in fossil fishes, and the general morphology of the same so far as it could be traced.

On referring to the works of Traquair, Karl Zittel, Smith Woodward, Pander, and others, it was very evident that a large amount of interesting evidence was to be obtained by a careful examination of fossil material.

My best thanks are due to Dr. R. H. Traquair, F.R.S., and Dr. Henry Woodward, F.R.S., for the permission to examine the collections of fossil fishes in the Edinburgh and British Museums. I am under the deepest obligations to Mr. A. Smith Woodward, F.G.S., F.Z.S., of the British Museum, for the assistance he has at all times so willingly given, for his valuable opinion in cases of difficulty, and generally for numerous kind-

nesses he has shown me. My thanks are likewise due to Mr. W. Eagle Clarke, F.L.S., and Mr. J. G. Goodchild, F.G.S.

It is unnecessary here to enter into any account of the Sensory Canal System of fishes, beyond stating that in recent forms we find a closed canal or open groove, passing from the caudal fin to the head, the sides of which it traverses, and then divides into three main branches, viz.: (1) An operculo-mandibular (or hyomandibular); (2) a supra-orbital; and (3) a suborbital. There are usually two commissures present; in a few cases three have been observed.

As might naturally be expected, the evidence obtained from an examination of fossil fishes is very fragmentary, and in not a few cases of a doubtful nature. In the following pages I have stated only that evidence which, after the careful examination of some hundreds of specimens, is, I think, trustworthy. I have endeavoured to avoid, as far as possible, any theoretical matter, contenting myself with having brought the subject under the notice of palæontologists, and trust that future investigations will reveal further and more satisfactory evidence.

The classification here followed is that adopted by Mr. A. Smith Woodward, in the published volumes of his "Catalogue of the British Museum Fossil Fishes."

PTERASPIDÆ.

Genus Pteraspis, Kner and Huxley.

Pteraspis crouchi, Lankester.

The specimen examined (42163)* has already been described and figured by Mr. A. Smith Woodward (11). It is a portion of the dorsal shield, and shows very plainly the canals which branch and open by minute pores. The smaller branches and pores seem not unlike some of the finer dendritic branches I have figured in the so-called squamosal of *Lepidosteus*.†

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* The figures in parenthesis are the numbers of the specimens in the British Museum collection.

† Proc. Birmingham Phil. Soc., 1893, vol. viii., p. 265, pl. v. fig. 3.

Genus Palæaspis, Claypole.

Palæaspis sericea, Lankester.

Under the generic name of *Holaspis*, this dorsal shield (P. 4117) was described and figured by Lankester in 1873 (3). The canal system, if such it really is, is very faint.

ASTEROLEPIDÆ.

Genus Pterichthys, Agassiz.

Traquair has described and figured the canal system in this genus, and points out that they have often been mistaken for sutures. The canals consist of grooves, and commence on the posterior dorso-lateral plates of the body, passing on to the anterior lateral plate, and dividing on the external occipital. There is an occipital commissure passing across the median occipital and joining with the canal of the opposite side. The main canal passes forwards and through the lateral cranial plate, and turns inwards on the premedian plate, and joins again with its fellow of the opposite side. In the centre of the premedian plate there is a slight inward flexure. There are no traces of any grooves on the extra-laterals or upon the arms.

Genus Bothriolepis, Eichwald.

In *Bothriolepis* the canals are somewhat more complicated. A canal enters the head on the lateral occipital plates, and passes forwards to the anterior portion of the laterals, from which point an occipital commissure is directed backwards, meeting in the hinder portion of the median occipital in a sharp angulation. A ventral groove passes vertically across the laterals, and an anterior commissure across the premedian plate, in the centre of which it forms an angular flexure.

On the dorsal surface of the body, a groove having the form of an inverted V, passes from the centre of the anterior median dorsal plate in a backward and lateral direction over the posterior dorso-lateral plate.

PHANEROPLEURIDÆ.

Genus Phaneropleuron, Huxley.

Phaneropleuron andersoni, Huxley.

In the specimen 26117a in the Edinburgh Museum, there are faint traces of a dorsal lateral canal in the anterior portion of the body. In the middle portion of the body the canal is scarcely discernable. There is also a faint trace of a ventral canal?

CTENODONTIDÆ.

Genus Ctenodus, Agassiz.

Faint traces of the lateral canal were seen in a number of specimens, in none of them were any points of special interest noted.

COCCOSTEIDÆ.

Genus Coccosteus, Agassiz.

Traquair, I believe, was the first to describe and figure the canal system of this genus (*C. decipiens*, Agassiz). The system forms a great network over the dorsal and lateral portions of the anterior of the body. There is no trace of any groove on the posterior dorso-lateral plates. I think it very probable, however, that the canal commenced on the posterior lateral plate and passed across the anterior dorso-lateral, from the anterior portion of which a backwardly directed commissure runs, forming an angulation in the posterior portion of the median lateral. There is no true occipital commissure. Passing forwards into the exoccipitals a bifurcation takes place, the lateral branch passing into the marginal, which we will leave for the present and follow the course of the other branch, which continues forwards and inwards into the central, where it abruptly ceases. Returning to the lateral branch in the exocciptals and marginal, we find in the centre of this latter plate it again divides, into a short downward branch, which terminates at the interior border of the marginal, and a branch which passes through the post-orbital and joins with an orbito-maxillary branch. This latter forms a commissure in the centrals, and

bifurcates in the maxillary to form a suborbital and a maxillary branch.

Genus Phlyctænaspis, Traquair.

I have not examined any of the plates of the members of this genus. Traquair (9) describes the lateral canal system as being practically the same as that in *Coccosteus*. "The lateral groove," he writes, "commences on each side in the exoccipital plate near the postero-lateral angle of the shield. Running forwards and slightly outwards it passes on to the marginal plate, where it gives off a branch backwards and outwards to the edge of the shield, just behind the postero-external angle. The main groove then turns forwards and slightly inwards at an obtuse angle, and on passing on to the post-orbital turns on the middle of that bone acutely backwards and inwards, ending on or near the centre of ossification of the central plate. Just at the point where the backward turn commences, a short branch is given off which ends in the post-orbital angle or prominence.

Mr. Whiteaves represents the main groove as again continued forwards at an acute angle so as to end at the front of the shield near the anterior-orbital prominence. Judging from analogy with *Coccosteus*, one might expect it to do so, but this continuation is not exhibited in any of the specimens I have examined."

Genus Homosteus, Asmuss.

Practically identical with *Coccosteus*.

HOLOPTYCHIIDÆ.

I have examined a very large and fine series of this family. Writing of this system in the *Rhipidistia*, Smith Woodward states: (10), "A lateral line arising immediately above the operculum traverses a longitudinal series of scales as far as an undetermined point on the caudal pedicle; and, at least in the *Holoptychiidæ*, there is another similar line arising from the jugular plates of either side. In the *Holoptychiidæ*, the sensory canal-system seems to form merely grooves in the exoskeleton; while in the *Rhizodontidæ* and *Osteolepidæ* it usually perforates the bones,

and is especially conspicuous upon parts of the head from the series of dot-like apertures by which the closed canals open externally."

Genus Holoptychius, Agassiz.

Holoptychius flemingii, Ag.

In a specimen in the Edinburgh collection, the following particulars were made out:—There are faint traces of a somewhat large canal in the preopercular bone, and traces on the upper and lower jaws of a series of cluster pores, which would seem to indicate that they originally were somewhat of the form found in such Ganoids as *Polyodon* and *Psepherus*. The traces of the lateral canal are only very faint. Unlike the condition known in any recent fish, it has a diagonal position.

(26 117. b.) On the post-frontals of this specimen there is present a radiating canal system. The greater portion of the surface of the bone is absent, and I think the canal *passed through the bone*, and not as an open groove as mentioned above by Mr. Smith Woodward. In (37301) there seem traces of a canal system in the parietals, particularly the left one; (26119) shows traces of a canal upon the dorsal and ventral surfaces.

In the *Holoptychiidæ* there were probably two dorsal canals passing from the caudal fin to the supra-temporals and along the sides of the head, branching in the parietals, and also in the post-frontals; also two ventral canals which passed around the mandible, but what the condition of termination was, and where, I am unable to say, none of the specimens that I have examined offering any reliable evidence.

Genus Glyptolepis, Agassiz.

Pander figures a scale. Huxley also figures one from Wick, in which, what I take to be branches of the lateral canal are present. There is a well-marked lateral canal.

Genus Rhizodopsis, Young.

There are traces of a canal, the supra-temporal bone giving off a branch to form an occipital commissure, and another in the squamosal and post-frontal.

There has been, and still is, a great difference of opinion as to the signification of these elements termed here squamosal, post-frontal, &c., and as the presence of a canal in them throws some light upon the subject, I venture, at the cost of repeating a number of well-known facts, to very briefly refer to the matter.

In a large number of both recent and fossil Crossopterygian Ganoids there are a series of small bones or ossicles, which conduct a sensory canal, running on either side of the parietals and frontals, and a similar chain across the occipital region. They are subject to much variation in form and number (*e.g.*, *Polypterus*), and were originally elements for the protection and carriage of the sensory canal. In certain genera they have become fused together, and possibly also with the cranial elements. Traquair (6) thinks it well to follow Huxley and term these squamosal and post-frontal; I think, however, at present it is better to regard them simply as canal bones.

Family OSTEOLEPIDÆ, Smith Woodward.

Genus Osteolepis, Valenciennes.

I have attempted a restoration of *Osteolepis*, partly after Pander, and from specimens examined. The main canal enters the head in the supra-temporal, and gives off in that region an occipital commissure. The main canal passes through three lateral cranial elements, probably comparable with the squamosal and post-frontal of recent Ganoids; it continues forwards and forms a supra-orbital branch, but I have been unable to trace any connection between this and the suborbital; in all probability one existed, so I have dotted and queried a connection, for we know of no form in which the suborbital branch is distinct from, and has no connection with, the main canal; and it seems probable that in those cases where the operculo-mandibular branch has been described as having no connection with the main canal, a more careful examination will show a many such opinions to be erroneous. In *Osteolepis*

the supra-orbital terminates in an anterior commissure, whilst the suborbital passes from this commissure beneath the orbit, and in a circuitous course through the preoperculum and along the mandible. What I am terming preoperculum is probably the cheek-plate, and the small element in the lower and posterior portion really the true preopercular element, not unlike the condition found in *Polypterus*.

PALÆONISCIDÆ.

Genus Canobius, Traquair.

On specimens of *C. ramsayi*, Traquair, which I have examined, there is a very distinct lateral canal (Trans. Roy. Soc. Ed., 1881, XXX., p. 47, pl. 5, fig. 1).

On some of the scales on the anterior dorsal surface of *C. elegantulus*, Traquair (Edin. Mus.), there are pores present. The lateral canal is very distinct, and is enclosed in a series of scales which have the appearance of short tubes, for in certain places (anteriorly) where the scales are slightly damaged they can be seen projecting slightly, and a distinct perforation is visible.

(4069). Shows the scales very similar to the Edinburgh specimen; the same feature is also seen in *C. pulchellus*, Traq. (4067).

Genus Rhadinichthys, Traquair.

The lateral canal is clearly marked. In none of the British Museum specimens was I able to find any traces on the head; in the Edinburgh Museum, however, there is a specimen of *R. geikei*, Traquair, in which there are faint traces of the canal in the supra-temporal region.

Genus Holurus, Traquair.

In *H. ischypterus*, Traq. (Edin. Mus.), the lateral canal is fairly well indicated.

PLATYSOMATIDÆ.

Genus Mesolepis, Young.

M. rhombus, Traq. (*Ann. and Mag. Nat. Hist.*, 1890, vol. vii. (6 ser.), p. 493). The only trace of a canal system is in the preoperculum, where there is a ridge passing in a downward direction.

Genus Platysomus, Agassiz.

In a very fine specimen of *P. gibbosus*, Agas. (35530), the lateral canal is very clear, but there are no traces upon the head. In *P. rhombus*, Agas. (1605), faint traces are visible of the preopercular branch.

LEPIDOTIDÆ.

Genus Lepidotus, Agassiz.

There are traces of both ventral and dorsal lateral canals (6336), the circumorbital bones are numerous, the preoperculum is distinct and large and shows a branched preopercular branch; there are traces of a mandibular branch also.

Genus Heterolepidotus, Egerton.

(3576). Lateral canal present, passing through a series of scales with vertical slits in their centres.

Genus Pholedophorus, Agassiz.

In the magnificent collection of the members of this genus, in the British Museum, I was able to trace a very large proportion of the canal system. In most of the specimens there are traces of a distinct lateral canal; in number 1071 it is large and well marked, and makes a sudden turn in the region of the clavicle. There is a well-marked suborbital branch which branches in the first two suborbital bones, and continues forwards, ultimately passing into the maxilla.

DAPEDIIDÆ.

Genus Dapedius, De la Beche.

The lateral canal seems to travel in the thirteenth row of scales from the ventral surface, at least this is so in speci-

mens 36258, 3554, and 35793. From the specimens examined, viz., 5937, 3539, 3541, 3551, 3554, 3555, 3563, 3564, 3567, 40090, and 1592, traces were found of a canal which branched in the posterior portion of the parietals, and travelled forwards along the squamosal; in 3539 this is very clearly shown. In 1592 traces of a mandibular canal were seen, and in 40090 a maxillary branch was found. In pl. 1, fig. 4, I have attempted a restoration of the system from the traces found in the above specimens.

Compared with *Lepidotus*, the system seems almost the same, only no trace was observed here of a dorsal lateral canal. Such fragmentary evidence as is to be obtained from the sensory canal system tends, I think, to support Dr. Traquair's conclusion that "the resemblances between the *Platysomidæ* and the *Dapediidæ* and *Pycnodontidæ* are mere resemblances of analogy, and not of affinity."

Genus Leptolepis, Agassiz.

In *L. dubius*, Agassiz (37074), the preopercular branch is beautifully shown, and thirteen branches ramifying the posterior portion of the bone; in 37044, six branches are visible; there are also thirteen branches in 37825, though they are not as well marked as in the above form. In one specimen a very distinct suborbital canal was seen with three branches. In a specimen of *L. crassus*, Agassiz, 37861, a preopercular branch with fourteen smaller branches, and a suborbital branch with five smaller branches; the same features are well marked in (p. 927) *L. latus*, Agassiz.

Genus Thrissops, Agassiz.

P. 915. *T. salmonens*, Agassiz. There is a preopercular branch present, and a distinct canal passing ventrally on the posterior border of the orbit; it passes beneath the eye and across a cheek-plate or large suborbital bone. The same features are seen in smaller specimens, *e.g.* 3680, and in *T. clupeoides*, Wentel (p. 916).

Genus Gyrodus, Agassiz.

The specimens in the British Museum do not show the interrupted series of pits in the main canal and supra- and sub-orbital branches, but Prof. Karl A. Zittel informs me that the canal in the specimen from which his illustration was taken (12. p. 239, fig. 251) looks like an interrupted line. It is not unlike that described and figured by Garman in *Chimæra* (1).

Summary and Conclusion.

Although the evidence here advanced is only of a very fragmentary character, there is sufficient to justify the following conclusions :—

1.—That a large number of Fossil Ganoids (*Holoptychius Lepidotus*, &c.) possessed two lateral canals, a dorsal and ventral one; a trace of the dorsal one still exists in *Polypterus*.

2.—That the canal system of the head in very many forms closely resembled the condition found in recent Ganoids, many forms exhibiting in addition a branched condition of the sub-orbital branch ; in fact, there seems to have been a general tendency for the main branches to divide into smaller ones, and ramify the numerous small cranial elements termed suborbitals, supra-temporals, &c.

3.—The preopercular branch, generally speaking, was similar to that found in *Amia calva*, the branches, however, were often much longer and more numerous.

4.—In certain of the earlier and generalised Ganoidei, the whole system resembled in many ways the condition found in many of the recent Selachians.

Explanation of the Figures.

Fig. 1.—a., Scale from the abdominal region of *Holoptychius flemingi*, Ag., b. and c., from the caudal region (after Smith Woodward).

Fig. 2.—Portion of the shield, dorsal aspect, of *Pteraspis crouchi*, Lankester, showing sensory canal, smaller branches, and pores.

Fig. 3.—Modified outline (after Traquair) of the head and dorso-lateral portion of the body-cuirass of *Coccosteus decipiens*, Ag. Canal system shown in red. m.o., median occipital; e.o., external occipital; m., marginal; c., central; pt.o., post-orbital; p.o., preorbital; pt.e., posterior ethmoidal; a.e., anterior ethmoidal; p.mx., premaxillary; n., nasal opening; mx., maxillary; mn., mandible; j., jugal; o., orbit; m.d., median dorsal; a.d.l., anterior dorso-lateral; p.d.l., posterior dorso-lateral; a.l., anterio-lateral; p.l., postero-lateral; i.l., inter-lateral.

Fig. 4.—Modified outline (after Traquair) of the head of *Dapedius*. Restoration of sensory canal system shown in red. Lettering as below.

Figs. 5 and 6.—Modified outline (after Pander) of the head of *Osteolepis*. Restoration of sensory canal system shown in red.

Fig. 7.—Restoration of head and sensory canal system of *Osteolepis*.

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Lettering of Figures.

Ag.	Angular.
D.	Dentary.
Br.	Branchiostegal.
C.b.	Canal bones.
Cl.	Clavicle.
Fr.	Frontal.
Ju.	Jugal.
M.	Mandible.
Md.	Mandibular branch.
M.c.	Main canal.
Mx.	Maxilla.
N.	Nasal opening.
Na.	Nasal.
Op.	Operculum.

Or.	Orbit.
Pa.	Parietal.
P.mx.	Pre-maxilla.
S.cl.	Supra-clavicle.
S.o.	Suborbital branch.
S.oc.o.	Supraoccipital commissure.
S.op.	Sub-operculum.
?	Probable connections.

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I.—*A Platinum-Strip Radiator.*

By P. L. Gray, B.Sc., A.R.C.S.

[Read before the Society on November 16th, 1894.]

Although experiments on Radiation have been carried on by many observers (notably by Leslie, Melloni, &c.), there has always been a want of an arrangement by means of which a surface, in a known physical condition, could be kept at high, known temperatures. "Leslie's Cube," a metal vessel which can be filled with liquid and heated, provides for accurate work at low temperatures—say, anything below the boiling-point of mercury—and by means of it reliable results may be obtained as to the comparative radiating powers of different surfaces. Attempts have also been made to

perform similar experiments at high temperatures by holding discs of metal, &c., in a Bunsen flame, but the method is open to many objections. The principle of the instrument now to be described is due to Prof. Joly of Dublin, who adopted it as a means of determining the melting-points of minerals, whence he gave it the name of "Meldometer." Messrs. Wilson and Gray modified it in several ways, and used it as a radiator in their "Experimental Investigations on the Effective Temperature of the Sun," published in the Philosophical Transactions for 1894. As the instrument, thus modified, seems capable of large use in numerous experiments on Radiation, and as the present writer has, by means of a grant from the (late) Birmingham Philosophical Society, had one constructed, with which he has begun a series of investigations at Mason College, a description of it may be of interest to the readers of the Journal.

The essential part is a ribbon of very thin platinum, of which the approximate dimensions are—

Length . . .	102 mm.
Breadth . . .	12 ,,
Thickness . .	0·01

This strip can be heated by an electric current to any desired temperature; as it becomes hotter, it also becomes longer, and its linear expansion is indicated by means of a mirror, suitably attached, which reflects a spot of light on to a scale at some distance. The mirror and scale are so arranged that the expansion due to a rise of temperature of 1°C may be observed.

The point then is, how is the actual temperature at any moment to be known? The answer to this question is essentially due to Joly. In Wilson and Gray's form of the instrument, the plane of the strip is vertical, but there is a very narrow ledge turned up along its lower edge, on which a minute fragment of any selected mineral may be placed. This fragment is viewed through a low-power microscope, by means of which the sudden melting of the fragment is distinctly seen, as soon as the temperature of the strip reaches the proper point. At this moment the spot of light will occupy a certain position on the scale, and (relative positions,

&c., remaining unchanged) when the spot of light is in this position on any future occasion, the temperature of the strip must be the same as during the first experiment. If, then, minerals be selected, the melting-points of which have been accurately determined, scale-readings and their corresponding temperatures may be plotted down, and a curve thereby constructed, from which the temperature of the strip may be known at any moment, up to and beyond the melting-point of the most refractory mineral used. As a matter of fact, it is generally sufficient to use two substances, the melting-points of which have been carefully determined—silver chloride (451°C.) and gold (1041°C.). The resulting curve is so near a straight line that intermediate readings, and readings beyond the gold-point, may be used to give the temperature of the strip at any moment, up to a limit little short of the melting-point of platinum (which is about 1750°C). Having thus obtained a surface of platinum which may be kept at any required temperature, all the ordinary experiments on radiation may be repeated and extended, as the strip can be coated with any desired substance, and the radiation comparatively measured by any instrument adapted to the purpose, such as a thermo-pile, a radio-micrometer, &c. Such experiments have already been partially carried out by the writer and Mr. W. E. Wilson.

A difficulty arises in working with a blackened surface at high temperatures; lamp-black burns off in air at something over 400°C.: black oxide of copper alloys with the platinum and becomes metallic in lustre at about 900°C.: platinum-black reverts to the metallic condition near the same point. If the strip, blackened with lamp-black, could be kept in a vacuum, or in an atmosphere of some inert gas, this difficulty would be obviated. For this purpose I have had a gun-metal box constructed, the lid and top edges of which have been carefully worked to planes true enough to enable a fairly good vacuum to be maintained within. The radiator is placed within the box, and it is hoped that by this means experiments at higher temperatures may be carried out.

Meanwhile, some interesting results as to the "minimum temperature of visibility" have been obtained. Both from a

physical and physiological point of view, the question "To what temperature must a solid body be raised, to become intrinsically visible in the dark?" is worthy of investigation; Draper, fifty years ago, gave an unsatisfactory answer to it, viz., 525°C. With the improved apparatus described above, it appears that the minimum is variable, according to the state of the observer's eyes; the less these eyes have been fatigued by exposure to a bright light, the lower is the temperature required to produce visibility. For instance, after being in a room on an ordinary light day, the minimum is about 460°C, but after complete rest in darkness at night, it is as low as 373°C.

A full account of the experiments on this point appeared in the *Philosophical Magazine* for June, 1894. (Vol. 37, 5th series, p. 549.)

It is intended to use the same apparatus for *absolute* measurements of radiation at different temperatures. For this purpose, the energy expended per second per sq. cm. may be determined by measuring the current and the fall of potential along the strip.

But even without the absolute measurements, comparative results with the radio-micrometer will give valuable information on the "law of radiation," *i. e.*, the connection of radiation with temperature, concerning which, at present, much uncertainty exists.

II.—*Some Researches upon the Sensory Canal System of Ganoids.*

By Walter E. Collinge, F.Z.S.,

Demonstrator of Zoology and Comparative Anatomy, Mason College, Birmingham.

[Read before the Society on October 16th, 1894.]

The following is a brief summary of a series of researches upon the Sensory Canal System of Ganoids. The work has been largely aided by a grant from the Endowment of Research Fund, and I take this opportunity of thanking the Council for their generous assistance.

Details of these researches have already been published *in extenso* in the Society's Proceedings,[1&2] the "Reports of the British Association,"[3] and the "Quarterly Journal of Microscopical Science."[4]

I now wish to summarise the work upon two types, viz., *Polyodon* and *Acipenser*, and upon the group as a whole.

The nomenclature adopted in all the above mentioned papers, and in the present one, is as follows:

The general system of canals, branches, sense-organs, &c., is spoken of as the *sensory canal system*.

[1] Proc. B'gham. Phil. Soc., 1893, vol. viii, pp. 255-62, pl. i-iii.
[2] ,, ,, ,, ,, ,, ,, pp. 263.72, pl. iv-ix.
[3] British Association Report for 1893 (1894), pp. 810-11.
[4] Quart. Jour. Micros. Science, 1894, vol. xxxvi, p. 499-537, pls. 39-40.

The canal on the lateral portions of the trunk is termed the *lateral canal*, that portion of it which is contained on the head, the *main canal*, with its branches as follows: *supra-orbital*, *sub-orbital*, *operculo-mandibular* or *hyomandibular;* and the *supra-occipital*, *pre-frontal*,[1] and *ethmoidal* commissures.

The fine dermal canals passing off from the main canal or any of the branches, and opening to the surface by a series of finer branches and isolated pores are spoken of as *cluster pores.*

Small pore-like openings, termed "pin-hole" pores by many authors are here spoken of as *primitive pores.* The term *sensory organ* is used for the series known as smell-buds, sense-organs, pit-organs, Merkel's buds, branchial sense-organs, &c.

POLYODON FOLIUM.

The canal system is largely developed and resembles in not a few features that found in the Elasmobranchii.[2]

1. The Lateral Canal commences on the dorsal caudal fin as a fine dermal canal passing along the sides of the body and on to the head on the lateral border of the post-temporal region. On the sides of the body and caudal fin the lateral canal gives off some thirty-two to thirty-five branches, each branch terminating in from four to seven smaller branches each of which finally ends as a pore. These are the cluster pores. Other sensory organs were found on the sides of the body which are probably modified cluster pores. In structure they resemble very closely the sensory follicles described by Fritsch,[3] who speaks of them as "spalt-papillen," externally they are not unlike the "seitenorgani" in *Petromyzon* figured and described by Leydig[4] (Taf. viii, fig. 13, b), only smaller. A further series of sensory organs were present in the region traversed by the lateral canal, but were not sufficiently well preserved to admit of microscopical investigation.

[1] I have previously termed this pre-orbital, as, however, it varies in position slightly the term pre-frontal is better.

[2] Bull. Mus. Comp. Zoöl., Cambridge, U.S.A., 1888, vol. xvii, pp. 59-119, pls. i-liii.

[3] Die Electrischen Fische, du Torpedinen. Leipzig, 1890.

[4] Festschrift d. Naturf. Ges. zu Halle, 1879, pp. 1-58, Taf. vii-x.

2. The Main Canal of the Head. The continuation of the lateral canal from the lateral border of the post-temporal region forms the main canal. It commences as a dermal canal but soon enters a canal bone and traverses the region of the dermo-sphenotic in the anterior portion of which it divides into three branches, viz., (1) the *supra-orbital*, which passes over the posterior lateral border of the frontal, across the dermo-ectethmoid and between the nasal openings; (2) the *sub-orbital* which is conducted around the posterior and inferior borders of the orbit in a series of small canal bones and meets with the supra-orbital, the two passing as a single canal along the ventral and lateral borders of the parasphenoid, in the anterior region two branches are given off and the canal diverges laterally, passes around the anterior border of the rostrum and joins its fellow of the opposite side; (3) the *hyomandibular* passes over the region of the hyomandibular bone to the angle of the mouth, where it divides into a maxillary and mandibular branch. In its course from the dermo-sphenotic across the hyomandibular region it gives off twelve small branches similar to those in the lateral canal.

The whole of the head, rostrum, and gill-flaps are covered by groups of primitive pores; some 3,500 groups were counted, the number of pores in each group averaging from seven to seventeen. There are also present on the head and sides of the body one hundred and thirty-two groups of cluster spores, distributed as follows:

On each side of the head . . .	12	= 24
On the dorsal surface of the head .	38	= 38
On each side of the body . . .	35	= 70
		132

INNERVATION OF THE CANALS.

The innervation proceeds from the trigeminal, facial and vagus nerve groups. It is of interest to find a part of the trigeminal innervating any portion of the canals, for in the Elasmobranchii it has been shown by Ewart and Mitchell[1] that only the facial and vagus supply the canal system.

[1] Trans. Roy. Soc. Edin., 1893, vol. xxxvii, pp. 59-86, pls. i-ii and pp. 87-106, pl. iii.

The conclusions I have reached respecting the distribution and branching of the facial are very different to those of Van Wijhe,[1] who has studied the cranial nerves of *Polyodon*, for a fuller discussion of these I must refer the reader to a recent paper [2] and the figures therein.

Trigeminal Group.

Ramus mandibularis.—Sends branches to the primitive pores in the region of the maxilla.

Ramus oticus.—Innervates the cluster pores lying between the spiracle and occipital region.

Facial Group.

Ramus buccalis.—Innervates the combined supra- and sub-orbital branches of the main canal of the head, also the primitive pores in that region, and on the lateral and ventral portions of the rostrum.

Ramus mandibularis.—Innervates some of the primitive pores on the sides of the head and the mouth.

Ramus opercularis superficialis.—Part innervates the hyomandibular branch of the main canal and the two branches in the upper and lower jaws, also the primitive pores on the sides of the head and gill-flap.

The distribution of the glossopharyngeal and vagus was similar to that found in the Elasmobranchii.

ACCIPENSER STURIO.

The Lateral Canal is conducted along the sides of the body by traversing alternating series of small disc-like canal bones on isolated scutes.

The Main Canal passes through the lateral border of the post-temporal, and forwards through the epiotic and squamosal. In the former it gives off an *occipital commissure*, and in the centre of the latter it divides into *supra-* and *sub-orbital* branches. The supra-orbital branch passes through the frontal and between the

[1] Neiderland, Arch. f. Zool., 1882. Bd. v, pp. 207-320, T. xv-xvi.

[2] Op. cit.

nasal apertures and continues on the dorso-lateral border of the rostrum. In the anterior portion it meets with the sub-orbital branch. This latter branch after leaving the main canal enters the pre-frontal and passes into a series of circumorbital bones. Leaving these it becomes a dermal canal for a short distance, soon it enters a series of canal bones and passes along the ventral and lateral borders of the rostrum. In the anterior portion it meets with its fellow of the opposite side.

Primitive pores are present in *Accipenser* on the ventral surface of the rostrum. There are no cluster-pores.

"*Polyodon* differs from *Acipenser* in—

(*a*). The canals being largely dermal ones, e. g., the lateral canal part of the main canal of the head and its branches—none passing through any of the cranial elements.

(*b*) The presence of branches on the lateral canal and on the hyomandibular branch of the main canal.

(*c*) The absence of commissures.

(*d*) The peculiar course and coalescence of the supra- and sub-orbital branches, by which a single canal is formed which does not pass along the lateral borders of the rostrum, but on either side of the parasphenoid.

(*e*) The presence of small mandibular and maxillary branches, a feature of great interest considering the many Elasmobranch affinities of the fish.

(*f*) The presence of cluster pores and other sensory organs on the lateral canal.

The sensory canal system of *Polyodon* agrees with that of *Acipenser* in—

(*a*) The presence of a lateral and main canal with supra- and sub-orbital branches.

(*b*) The presence of a series of small bony elements—drain-pipe-like canal bones—conducting either the canals or their branches.

(*c*) The presence of primitive pores upon the head.

(*d*) The absence of either a pre-orbital or an ethmoidal commissure."

COMPARISON AND REVIEW OF THE SYSTEM IN THE GANOIDEI.

"In comparing the sensory canal system in the existing Ganoids, it must be borne in mind that they are an order of fishes the families of which are widely separated from one another, the intervening gaps being but very imperfectly bridged over by a series of still less perfect extinct forms whose fossil remains show, in most cases, few if any indications of the source of this system of canals.

Of the eight known genera of recent Ganoids I have examined specimens of all excepting *Scaphirynchus*, which in all probability is very similar to *Acipenser*.

The Polyodontidæ are undoubtedly the most generalised family, and most closely related to the Elasmobranchii.

In the Aciperensiidæ we have a great advance upon anything seen in either of the genera in the preceding family, and yet the absence of mandibular and maxillary branches and the persistence of large numbers of primitive pores are features which are truly Selachian. *Acipenser* is the first species in the class Pisces in which the canal or its branches enters into the cranial elements.

Of the Teleosteoid Ganoids we have three families widely separated from one another.

The most interesting feature in the Lepidosteidæ is undoubtedly the greatly developed system of dendritic branches passing off from the main canal and entering into the various cranial elements. These fine branches anastomose and form a dense network. In this feature the system resembles in many ways that present in the Selachians. There are no branches on the lateral canal. In the pre-orbital region there are a number of fine branches which anastomose and form a commissure connecting the two supra-orbital branches, a condition peculiar to *Lepidosteus osseus*, so far as is at present known.

The Polypteridæ show a number of features not previously met with. In *Polypterus* we note the absence of dendriform branching and primitive pores, and the small number of pores

generally, the presence of a branch from the operculo-mandibular branch, which passes across the cheek-plate, and a fine canal passing through the series of canal bones (= intercalary ossicles of Traquair) which connects the main canal of the head with the operculo-mandibular branch. There are also traces of a rudimentary or degenerate canal in the pre-operculum.

The system in *Calomoichthys* is practically the same as that described in *Polypterus*.

The family Amiidæ has been the most thoroughly studied of any of the Teleosteoid Ganoids. The branching of the lateral canal still persists in the posterior border of the scale, the canals of the head are almost wholly contained in the bones, dermal portions being exceedingly small. The cluster and primitive pores are much more specialised in character and fewer in number. There is little or no branching of the system upon the head, excepting in the pre-operculum, an operculo-mandibular branch being present. There is no connection between the two mandibular portions in the median symphysis of the lower jaw. Both occipital and ethmoidal commissures are present, and a similar form of branching in the pre-orbital region as was noticed in *Polyodon*."

II.—*Contributions to the Limb Myology of the Rodentia.*

2.—*Limb Myology of the Capybara (Hydrochœrus capybara).*

By T. Manners-Smith, B.A. Cantab., M.R.C.S.

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[Read before the Society on November 20th, 1894.]

The following is the second portion of a series of notes upon the limb myology of Rodents. It deals with the anatomy of Capybara compared with that of other members of the *Hystricomorpha*. Thanks are again due to Dr. Windle for kindly providing me with the specimen.

Muscles of Anterior Extremity.

Pectoral Group.—Adopting Windle's[1] classification, the following portions are present:—(a) *Superficial manubrial* (b) *Gladiolar* (c) *Costal* (d) *Abdominal*. *Superficial manubrial* is fused with *Gladiolar*, whilst *Costal* portion is fused with *Abdominal* portion. The muscle has the usual insertion into the pectoral ridge of humerus.

Deep manubrial is absent.

The *Sterno-scapular* muscle is long and narrow; it arises from the first piece of the sternum at its prominent anterior end; the

[1] Proc. Royal Irish Acad., vol. 29, p. 345.

muscle passes outwards and backwards and is inserted into the antero-internal angle of the scapular.

Deltoid arises from the acromion and metacromion; from the fascia over the *infra-spinatus*; and from the spine of the scapula. The muscle is inserted into the deltoid ridge of the humerus. It does not cover the shoulder joint. This muscle may be split up into two portions, anterior and posterior.

Supra-spinatus.—This muscle has the usual position, origin, and insertion.

Infra-spinatus.—Has the usual origin and insertion, but is intimately connected with *teres minor*.

Teres minor is so intimately blended with *infra-spinatus* that it is an artificial dissection to separate it.

Teres major arises from the axillary border of the scapula, close to the posterior angle. It blends with the *latissimus dorsi*, and is inserted with that muscle into the humerus, the muscles being covered at their attachment by the thin insertion of *coraco-brachialis*. The muscle is situated in front of *latissimus-dorsi*.

Triceps.—The long head arises just below the glenoid; it blends with the outer head just before the insertion of the muscle into the olecranon process. The outer head is intermediate in size between inner and long heads. It arises by an extremely thin flattened tendon from the back of the humerus, just below the head of the bone. It blends with the long and inner heads at insertion into olecranon. At its origin, it covers the outer part of *brachialis anticus*. The inner head arises from the inner and posterior surface of humerus close to head. It passes, entirely distinct from the long head (beneath which it is placed in its lower third) to its insertion into the olecranon, blending here, however, with the outer head. Its origin is concealed by the *coraco brachialis* and *latissimus dorsi*. The whole muscle is supplied by the musculo spiral nerve. In *Dasyprocta cristata*[1] it is very similar to above description.

Biceps.—This muscle arises by a single head from the top of the glenoid cavity. It is inserted chiefly into the ulna, but a

[1] Mivart, P.Z.S., 1866.

deeper portion of the tendon passes to the radius. An almost similar insertion of biceps occurs in *Cavia cobaya*[1]. The chief insertion in that animal passes to ulna, whilst the muscle is connected with radius only by a fascial band. The muscle is monogastric in *Hystrix* and *Cœlogenys*, whilst it is digastric in *Erethizon dorsatus*.[2]

Coraco brachialis. — Is a slender muscle arising from the coracoid by a narrow tendon; the muscle, after expanding in the middle, is inserted by an extremely thin tendon into the middle of the humerus. It represents the second portion of the typical muscle. In *Cavia cobaya* it is apparently the first portion of the typical muscle which is present, whilst in *Dasyprocta cristata*[3] the upper and middle portions appear to be present. In *Chinchilla*,[4] *Hystrix*,[4] and *Octodon* the second head only is present; whilst in *Erethizon dorsatus*[5] and *Erethizon epixanthus*[6] both the second and third heads are found.

Brachialis anticus.—The outer part only of this muscle is present. It arises from the posterior surface of the humerus, close to the head of the bone and beneath the outer portion of the triceps muscle. It is inserted into the ulna. In the fact that this muscle is single it agrees with *Cavia cobaya*,[7] *Sphingurus*, and *Chinchilla*[8], whilst in *Dasyprocta cristata* it is separated into two parts.

Dorsi epitrochlearis.—Is a broad, thin, triangular sheet, arising anteriorly in company with the *deltoid*. It is inserted into the olecranon. It covers the muscles of the back and inner sides of the arm, viz.: in the long and inner heads of triceps.

Muscles of the Forearm.

Pronator radii teres.—This muscle arises from the ento con-

[1] Mivart, P.Z.S., 1866, p. 399.
[2] Mivart, P.Z.S., 1887, p. 53.
[3] Mivart and Murie, P.Z.S., 1866, p. 399.
[4] Parsons, P.Z.S., 1894, p. 264.
[5] Mivart, P.Z.S., 1882,
[6] Windle, Jour. Anat. and Phys., vol. xxii, p. 126.
[7] Mivart and Murie, P.Z.S., 1866, p. 400.
[8] Parsons, P.Z.S., 1894, p. 265.

dyle of the humerus and is inserted into the middle of radius. From its insertion a fascial slip extends down to the scapho-lunar. In *Cavia* it has a similar insertion into the middle of the shaft of radius. In left limb of *Dasyprocta* there is a similar fascial tendon to that mentioned above, and which seems to be a continuation of the tendon of the muscle and appears to pass to the carpus.[1]

Flexor Mass.—*Sublimus* is a comparatively thin muscle arising from the ento-condyle; below it splits into three tendons, which, after being perforated in the usual way, pass to 2nd, 3rd, and 4th digits. The muscle goes to the three digits in *Dasyprocta*; in some cases it sends a tendon to the 5th digit, as it did on one side in Mivart's specimen. In *Cavia* it sends slips to 2nd, 3rd, 4th, and 5th digits.

Flexor profundus.—Adopting Windle's[2] classification *flexor profundus* consists of the following parts: (*a.*) *Ulnaris*, which is a distinct well-developed muscle, arises from the olecranon and whole length of the posterior surface of the ulna, and, curving forwards, it blends with *Condylo radialis* and *Ulnaris*, and may be traced to the 5th digit. (*b.*) *Condylo ulnaris.*—Is the larger superficial portion attached to the ento condyle, and forms the chief parts of the tendon. (*c.*) A smaller head, *Condylo radialis*, arising from the ento condyle beneath the superficial head. The two latter portions, after twisting in lower third of forearm, fuse at the carpus, and the tendon, after being dilated at the wrist, divides into four tendons which become the perforating tendons for the digits. (*d.*) *Centralis* is a small muscle arising from the ento condyle beneath the combined *Condylo-radialis and Condylo-ulnaris* and joining those muscles in their inner and deeper part. There are three well marked *lumbricales* arising from the *perforans* and passing to the radial sides of the 3rd, 4th, and 5th digits.

Flexor carpi ulnaris.—Arises from olecranon. It consists of two parts, a superficial and a deep. The superficial part blends with the fascia at the inner side of the carpus; the deep passes to the pisiform bone.

[1] Mivart and Murie, P.Z.S., 1866.

[2] Windle, Jour. Anat. and Phys., vol. xxiv, p. 72.

Pronator quadratus.—Is a thin sheet of muscular fibres extending obliquely downwards from ulna to radius, and reaching almost to elbow-joint.

Flexor carpi radialis.—Arises from the ento condyle. It passes deeply in the forearm, being here bound down to lower end of radius. It is inserted into the proximal end of the metacarpal bone of the 3rd digit. In *Cavia* and *Dasyprocta* it apparently goes to the first phalanx of the index.

Posterior Surface.

Extensor carpi ulnaris arises from ecto condyle by common tendon, and from olecranon. It is inserted into a small nodule of bone at the base of the metacarpal bone of the minimus, a portion of the tendon being prolonged to the shaft of the metacarpal bone of this digit.

Extensor communis digitorum is comparatively a rather slender muscle arising from the ecto condyle. Below it splits into five tendons: the first passes to the index; the second and third pass to the medius; the fourth passes to the annularis; the fifth, which is slender and comes off in the forearm, divides, passing chiefly to the minimus, but sending a slip to annularis. In *Cavia cobaya* and *Dasyprocta* the tendon is divided into two parts, the larger going to 3rd, 4th, and 5th, the smaller part to 2nd and 3rd in former animal; larger part to 2nd, 3rd, and 4th; smaller to 3rd and 5th digits in the latter animal.

Extensor minimi digiti.—There is a distinct *extensor minimi digiti* taking origin from the ecto condyle of humerus and from the ulna. It divides into two tendons, the larger passes to the 4th, the smaller to 5th digit. It has much the same origin and insertion in the *Cavia* and in *Dasyprocta.*[1] In *Sphingurus* it passes to the 3rd, 4th, and 5th digits.[2]

Extensor ossis metacarpi pollicis.—Arises from the radius and ulna, and is inserted into a small nodule of bone representing a rudimentary pollex, which articulates with the base of the second metacarpal. A small fascial slip is prolonged from this ossicle to

[1] Mivart and Murie, P.Z.S., 1866.

[2] Parsons, P.Z.S., 1894, 269.

the shaft of the metacarpal bone. *In Cavia cobaya* it is inserted into trapezium and sends a slip to pollex.[1] In *Dasyprocta* it passes to pollex.

Extensor primi et secundi internodii pollicis are absent in this animal and also in *Cavia* and *Dasyprocta.*

Supinator longus is absent as in *Cavia* and *Dasyprocta.*

Extensor carpi radialis.—There is a single muscle in the position of the radial carpal muscles, which arises from the ecto condyle of humerus. It splits in the lower third of the forearm into two tendons, which pass to the 2nd and 3rd digits where they are inserted. That for the 3rd divides before its insertion into two parts, one passing to the middle, the other to the proximal end of this digit. The muscle can be divided into two parts—the upward continuations of the tendons. It is, however, an artificial dissection so to separate the two portions.

In *Cavia* and *Dasyprocta* Mivart describes two muscles ; the muscles, in these animals are, however, very closely applied.

Interossei are very regular in their arrangement, a pair passing to each of the three outer digits, one on either side ; a single one passes to minimus. There is a well marked *abductor* and *opponens minimi digiti.*

Muscles of Posterior Extremity.

Psoas parvus arises from the upper three lumbar vertebræ, it is inserted into the pectineal eminence, and is a very slender muscle.

Psoas magnus consists of three well marked separate portions —internal, middle, and external. The internal portion, which is the lowest, is partly abdominal and partly pelvic ; the abdominal arises from the bodies of the lower lumbar and upper two sacral vertebræ ; the parts are entirely continuous and pass directly downwards and upwards and join the common tendon on its inner side. The middle portion arises from the bodies and costal processes of the lumbar vertebræ ; it also arises from the last two dorsal vertebræ ; below it passes into the common tendon.

[1] Mivart and Murie, 1866, P.Z.S., 404.

The external portion extends the highest; it arises from the heads of the lower ribs on the outer side, internally, from the bodies of the dorsal vertebræ, being here united with the internal part. Below it separates from the middle portion, which is superficial to it. In the lumbar region it takes origin by superficial, separate, tendinous slips from the costal processes, and these portions pass to be inserted into the upper border of the costal element of ilium, missing the main tendon of *psoas* and passing beneath it. The upper portion, that from the heads of the ribs and bodies of the vertebræ, passes to be inserted into the costal processes beneath the slips of origin of the lower portion of the muscle. The muscle is strongly marked by tendinous intersections.

Iliacus arises in usual situation from the iliac fossa and internally it joins the tendon of the *psoas.*

Muscles of the Thigh.

Quadriceps extensor.—Rectus femoris arises by a single tendon from the dorsum ilii, above the acetabulum and between the joint and the anterior spine; it also arises by a fascial band from the spine itself. These are, however, not two distinct tendons, for the attachment is continuous. Below it passes over the patella, receives the chief portion of the fibres of the *vastus externus*, and is inserted into the tubercle of the tibia. Mivart and Murie[1] describe a double tendon of origin in *Cavia cobaya* and *Dasyprocta.*

Crureus arises from the anterior, inner, and outer surface of the femur; below, it is inserted into the patella. A deep band of fibres passes from apex of patella to tubercle of tibia beneath *rectus femoris.*

The *Vastus externus* arises from the whole length of the outer surface of the femur; below, it passes inwards, overlaps the *rectus*, some fibres blend with *externus*, other (lower) fibres are inserted into tendon of *rectus* and to the side of the patella.

Vastus internus arises from the whole length of the posterior border of the femur and is inserted into the inner border of the patella.

[1] Mivart and Murie, P.Z.S., 1866, 409.

Gluteus maximus is a thin but extensive layer attached to the spines of the sacral and caudal vertebræ; on the outer side it is inseparable from the *tensor fasciæ femoris;* below, the combined sheet passes down, and gluteal portion is inserted into the fascia of the leg; a slender slip is also attached to lower part of femur. The anterior portion goes to the head of tibia.

Gluteus medius is a thick muscle arising from the sacro-coccygeal vertebræ and also from dorsum and crest of ilium. It is inserted into the great trochanter in the usual position. In *Cavia cobaya* it has a similar origin and insertion.

Gluteus minimus is a well-marked muscle; it arises from the anterior portion of the ilium by a narrow origin and passes to its insertion into the root of the peroneal trochanter. There is no separate *gluteus quartus* present.

Gracilis is an extremely thin sheet; it arises from the ischio pubic arch as high as the pectineal surface of the pubes; it is inserted by a fascial expansion into the inner side of patella and head of tibia. In *Cavia cobaya* and in *Dasyprocta* it is inserted as far down as the ankle.

Adductor group is separated into three parts. A posterior portion, arising from the tuberosity of ischium and passing to lower end of femur. The second is a thin intermediate portion, arising from the pubes and is inserted into the femur. This portion is in the position of the *adductor longus.* The third portion arises from the pectineal surface of the pubes and is inserted into the upper third of the femur. This last portion probably represents pectineus.

Hamstring Muscles.

Biceps arises from the sacro coccygeal vertebræ and from the tuberosity of the ischium. It is inserted by a wide expansion into the anterior side of the tibia and patella, and sends a fascial slip as far down as os calcis. In *Cavia* and *Dasyprocta* the muscle consists of two portions.

Semi membranosus arises from ischial tuberosity and is inserted into the inner side of the head of tibia by a narrow attachment.

Semi tendinosus arises from the tuberosity of the ischium; it is inserted into the head of the tibia by a broad fascial expansion. It is intimately united with the *gracilis* below. Above it passes into continuity with an *ischio coccygeus.* In *Dasyprocta,* too, its tendon blends below with that of *gracilis.*

Muscles of the Leg.—Anterior Surface.

Extensor communis digitorum arises from the lower end of the femur by a narrow tendon. It is not attached to the tibia. On the foot it divides into three tendons; the outermost of these passes to the outer of the three digits, also sending a narrow fascial slip to the middle digit; the middle tendon passes undivided to the middle digit; the third also sending a narrow fascial slip to the middle digit. It has a very similar origin and insertion in *Dasyprocta Cristata.* There is also a slender *extensor brevis digitorum* present possessing three fascial like tendons; two pass to the third digit, one to the second digit. In *Dasyprocta Cristata* two tendons only are present.

Tibialis anticus arises by two heads. A long tendinous head attached to the lower end of the femur on the outer side. This crossing the knee joint, pierces a portion of the short head and, becoming fleshy, blends with the belly of the muscle in the upper third of the leg. The short head arises from the anterior surface of the tibia, and joins the other portion as described above. The tendon of the muscle splits into two parts, the anterior is inserted into the metatarsal bone of the innermost digit, and is the more slender of the two. The posterior (larger) is inserted into the ento-cuneiform. In *Dasyprocta Cristata* this muscle has also a double origin, the muscle arising in a very similar manner to that described above, *i.e.*, by a fleshy tibial and tendinous femoral origin. It has in that animal, however, a single insertion. It has, according to Mivart, the same peculiarities in the Guinea pig.[1]

Parsons, however, did not find the femoral head in any of the three Guinea pigs he dissected;[2] neither did he find the femoral

[1] Mivart, P.Z.S., 1866, 411.
[2] Parsons, P.Z.S., 1894, 288.

head in *Dolichotis patagonea*, though the head was found by Beddard [1] in this animal. In the fact that it possesses a double insertion in this animal it differs from the condition existing in most rodents in which the pollex is rudimentary.[2]

Extensor longus hallucis is a slender muscle arising from the lower portion of the fibula ; it is inserted into the terminal phalanx of the innermost digit, *i.e.*, the index. This muscle is absent in *Chinchilla.*[3]

It is also a slender muscle in *Cavia Cobaya* and *Dasyprocta.* In that animal also it passes to the index.

Peroneus quarti digiti arises from the fibula, and from the strong intermuscular septum between it and the neighbouring muscles. It is inserted into the outermost digit. It is almost nearly similar in *Cavia cobaya* and in *Dasyprocta.*

Peroneus longus arises from the head of the fibula and from the strong tendon-like external lateral ligament, which appears to be a direct continuation of the tendon up to the lower end of femur ; below, it passes through a groove on the outer surface of the ex-malleolus of fibula, and from thence into the sole, where, crossing from without inwards, it divides into three slips. One passes to the additional ossicle at inner side of foot, the middle to the base of second metatarsal, the outer slip to third metatarsal. In *Cavia cobaya* the muscle passes in front of the malleolus, in *Dasyprocta* it passes behind the outer malleolus.[4]

Peroneus brevis arises from the lower end of fibula. It is inserted into a rudimentary fifth metatarsal at the base of the fourth metatarsal bone. It has a similar insertion in *Cavia cobaya.* This muscle is absent in *Dasyprocta Cristata.*

Gastrocnemius arises by the usual two heads. These heads are, however, peculiar in the fact that they themselves are again bicipital. One portion arises from the outer side of the patella, by a narrow tendon, which soon becomes fleshy and blends at an acute

[1] Beddard, P.Z.S., 1891, 236.
[2] Parsons, P.Z.S., 1894, 288.
[3] ,, ,, ,, 289.
[4] Mivart, P.Z.S., 1866, 412.

angle with the other portion of the outer head; this takes its origin in the usual situation, from just above the back of the outer condyle of the femur. The two portions form the outer head of the muscle which covers up the *plantaris*, and is joined a little above the middle of the leg by the inner head of the muscle. The inner head consists also of two portions, a superficial and a deep. The superficial, which is tendinous, has a broad origin from the inner surface of the internal condyle, its attachment extending as far anteriorly as the trochlear surface. The deep portion arises by short tendinous and muscular fibres from the bone in the usual situation, at the back of internal condyle of the femur. The tendon formed by the two heads passes downwards and slightly outwards, crossing the *plantaris*, and after passing beneath that muscle is inserted into the os calcis on either side in a similar manner to *plantaris*; the thin tendon, however, passes inwards into the sole, and extends as far as the bases of the metatarsal bones, where it gives origin to some of the short deep muscles of the hallux in a somewhat similar manner to the long plantar ligament in man.

Soleus arises from the head and upper two thirds of the shaft of the fibula. Its fibres are inserted into the posterior, inferior, and inner surfaces of the os calcis; they are quite distinct from the *gastrocnemius*, and the muscle is fleshy almost to its insertion.

Plantaris also arises by two short heads; the outer, tendinous, arises from the outer surface of the external condyle of the femur; this head passes from its origin here between the two parts of the outer head of *gastrocnemius* muscle. The inner head arises by short tendinous fibres from the posterior surface of the external condyle. The two heads blend close to their origin, and the muscle passes down to the back of the leg, under cover of the outer head and common tendon of *gastrocnemius*. In consequence of the twisting of the latter muscle to the outer side, the tendon of *plantaris* is exposed, and finally is situated superficially to the *gastrocnemius*; here it is at first very narrow, next expanding, thins out and passes over the os calcis. As the muscle passes over the os calcis it takes an attachment to the bone on either side, but

it is quite free and smooth on the under and posterior surface of the bone. The expansion divides into three tendons, which, after becoming the perforated tendons for the toes, are inserted into the second phalanges. A strong fascia binds the tendons together in the sole.

Flexor fibularis (*Flexor longus hallucis* of human anatomy). The muscle arises from the posterior surface of the head and upper three-fourths of shaft of fibula. Passing into the sole, its tendon expands and flattens somewhat. After receiving on its inner side the *flexor tibialis* it divides into three tendons; these tendons, after perforating the *plantaris* are inserted into the terminal phalanges of the digits. The tendons, as they pass along the digits, are bound down by a strong sheath, and are partially cleft on their surface over the second phalanx; each tendon divides into a thicker superficial portion and a deep thinner portion; both portions pass to be inserted into the terminal phalanx.

There are two slender *lumbricales* arising from the *perforans* and passing to the second and third digits.

Flexor tibialis (*Flexor longus digitorum* of human anatomy) arises from the posterior surface of the tibia, and is intimately connected above with the *popliteus*; passing into the sole it blends with the *flexor fibularis*, which is much the larger of the two flexor muscles; on its inner side its tendon may be traced chiefly to the second digit.

The muscle conceals the *tibialis posticus*, and afterwards passes with that muscle into the sole in a groove in the tibial malleolus.

Tibialis posticus is a narrow muscle; it arises from the posterior surface of the tibia, extending up as far as the head of the bone, a few fibres also take origin from the surface of the head of the bone. The muscle is placed beneath the *flexor tibialis*; and entering the foot through the same groove as that muscle is inserted into the additional ossicle, which articulates with the astragalus, scaphoid, and ento cuneiform.

These are five *interossei* muscles; two are single, three divided. Of the single, the first passes to the inner side of the first digit: the second to the outer side of the same digit. The

remaining are arranged very regularly, one to each digit; they arise together by a single origin, and the muscles split into two parts below; their tendons, passing to either side of the digits, one to each.

Lettering of Figures.

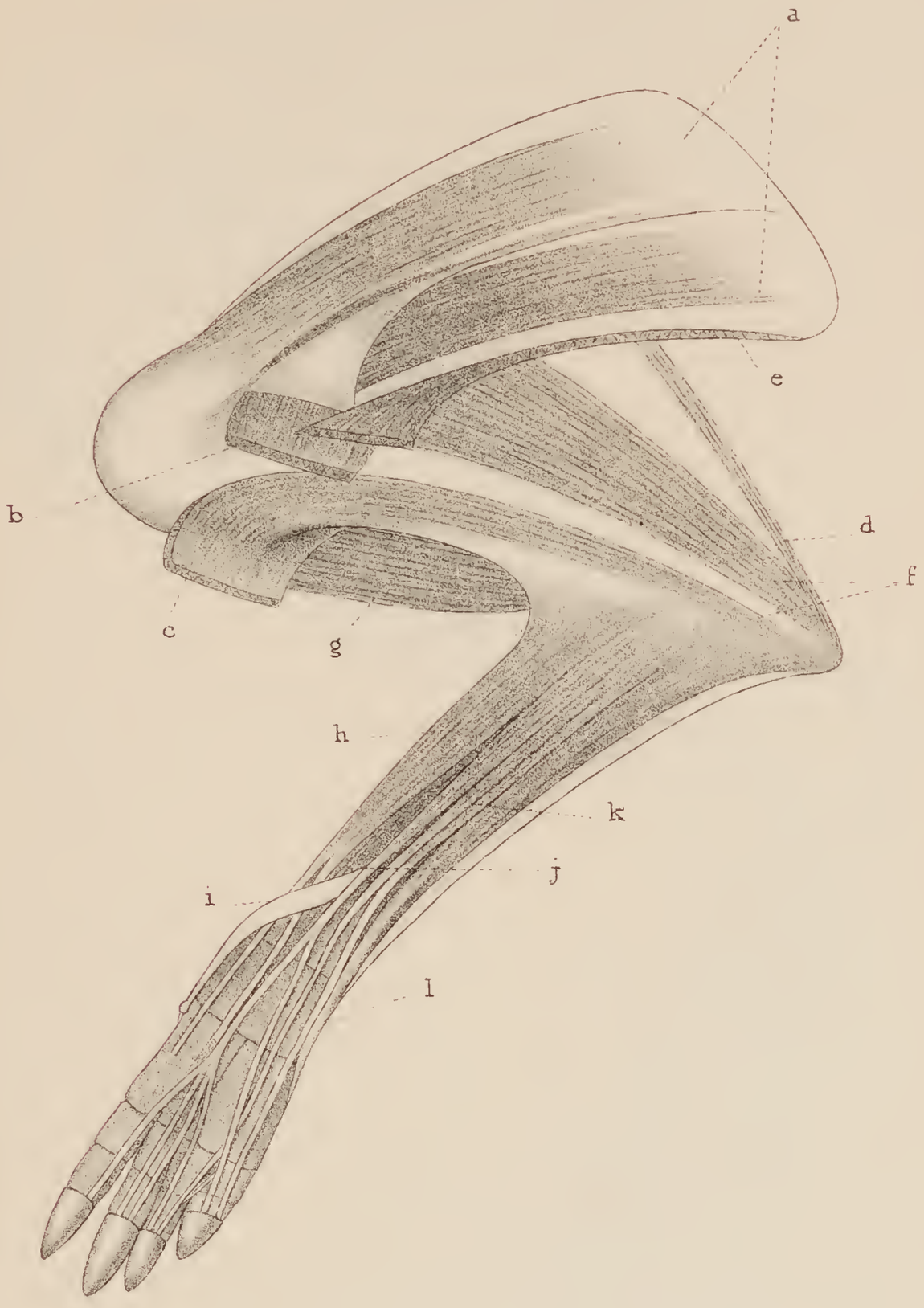
Fig. 1.—Fore-limb of *Hydrochœrus Capybara.*

- *a.* *Supra* and *Infra spinatus* muscles.
- *b.* *Deltoid.*
- *c.* *Pectoralis major.*
- *d.* *Dorsi epitrochlearis.*
- *e.* *Latissimus dorsi*, cut.
- *f.* *Triceps.*
- *g.* *Brachialis anticus.*
- *h.* *Extensor carpi radialis*, its tendon dividing.
- *i.* *Extensor ossis metacarpi pollicis.*
- *j.* *Extensor communis digitorum.*
- *k.* *Extensor minimi digiti.*
- *l.* *Extensor carpi ulnaris.*

Fig. 2.—Hind-limb of same.

- *a.* *Tibialis anticus*, its double origin shown above.
- *b.* *Extensor longus hallucis.*
- *c.* *Extensor communis digitorum.*
- *d.* *Peroneus quarti digiti.*
- *e.* *Peroneus brevis.*
- *f.* *Peroneus longus.*
- *g.* *Plantaris.*
- *h.* *Gastrocnemius.*
- *i.* *Soleus.*

Fig 1.



F.W Grispe del. Robert Birbeck, lith. Birm.

Fig. 2

F.W. Grispe del

Robert Birbeck, lith. Birm.

IV.—*On the Physical Characters of a Group of Birmingham Pupil Teachers (Female).*

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The following observations are based upon the measurements of two hundred pupil teachers under the Birmingham School Board, obtained by us at the Anthropometrical Laboratory of the Society, in the Athletic Institute. These subjects form a fairly homogeneous group as regards position and race. In two instances only have either of the parents distinctly foreign names, and in two others both parents would seem to be Jews. With these exceptions all the names are British, and many, perhaps most of them, are very familiar in Birmingham and the district. They may, therefore, be taken as representing a fairly characteristic group from a definite class of Birmingham girls.

The numbers obtained so far are not sufficient for each year of age to enable us to establish any just comparisons with other places

nor to fix a standard for future use in Birmingham. We, therefore, offer these observations as a body of facts, to which we hope to add in time, and at some future period to be in a position to make a more complete report upon the subject.

Before passing to the consideration of the observations made, this will be a convenient place for noting that of the two hundred sets of parents only three were first cousins.

I.—Colours of Iris and Hair.—We have arranged these observations on the lines of Dr. Beddoes' tables. The second line gives percentages, the first actual figures.

Eyes Light. Hair.						Eyes Intermediate. Hair.						Eyes Dark. Hair.					
R.	F.	Br.	D.B.	Bl.	Tot.	R.	F.	Br.	D.B.	Bl.	Tot.	R.	F.	Br.	D.B.	Bl.	Tot.
2	41	26	24	1	94	1	21	9	12	1	44	2	10	19	29	2	62
1	20·5	13	12	·5	47	·5	10·5	4·5	6	·5	22	1	5	9·5	14·5	1	31

With respect to these figures it should be observed that the iris tints are calculated from the test eyes used in Mr. Galton's laboratory, 1—1·5 being included under light eyes, 1·75—2·25 under neuter or intermediate, and the remainder under dark. There is thus not much room for error from the personal factor. It is unfortunately otherwise with the hair tints. There is at present no really satisfactory scheme of test tints, and as a consequence the determination by different individuals must vary considerably, and even that by a single person can scarcely remain constant and reliable over a long period of time.

II.—Cephalic Index.—This index has been measured in the ordinary manner, and the results worked out as follows.

Dolichocephalic,	Index below 74·9.	Total No. 22.	11 %.
Mesocephalic,	,, 75·0—79·9.	,, 93.	46·5 ,,
Brachycephalic,	,, above 80·0.	,, 85.	42·5 ,,

III.—Height.—The following table gives the numbers at different points for the various years examined. A few girls of nineteen and twenty years of age were omitted, the number examined being far too small to be worth recording.

	Years.			
Below Cm.	14	15	16	17	18
142	1	—	—	—	—
143	—	—	—	—	—
144	1	2	—	—	—
145	1	1	—	—	—
146	1	2	2	—	—
147	1	3	2	—	—
148	—	—	—	—	—
149	1	2	—	—	1
150	3	1	2	2	—
151	2	1	2	—	—
152	1	6	1	1	—
153	5	2	2	2	—
154	3	3	4	—	1
155	2	2	4	1	—
156	6	3	1	1	1
157	5	3	4	2	2
158	2	1	6	3	—
159	2	3	7	—	2
160	2	6	5	1	1
161	4	1	3	—	1
162	—	3	2	2	—
163	3	3	—	3	1
164	—	2	2	1	—
165	1	1	1	3	2
166	2	3	—	—	1
167	1	1	—	—	—
168	—	1	1	1	—
169	—	1	1	—	—
170	—	—	1	—	—
Totals	50	57	53	22	13

From the irregularities of the figures in the preceding table it will be observed, as has already been stated, that the number of observations is too small for accurate comparison with other statistics. For the sake, however, of affording a rough method of comparison, the following table shows in the first column the average stature for the various ages of girls in schools of all classes in Boston, U.S.A., as obtained by Professor Bowditch. The second column shows the number of Birmingham girls, so far as our statistics go, who are above or below the Boston average at each year of age. It will be observed that, so far as stature goes, and

these figures are reliable as an index of the general average, our pupil teachers have the advantage over the Boston school-girl.

Boston Girls. Av. Stature.		at	Birmingham Girls. No. below this Average.	No. above it.
Cm. 152·3 In. 59·94	14	years.	17	33
Cm. 155·2 In. 61·10	15	,,	28	29
Cm. 156·4 In. 61·59	16	,,	24	29
Cm. 157·2 In. 61·92	17	,,	8	14
Cm. 157·3 In. 61·95	18	,,	5	8

The ratio of stature to length of trunk (standing to sitting height), the latter being considered as the unit, was—

In 7 cases (3·5%), 1·7 ; in 111 cases (55·5%), 1·8 ; and in 82 (41%), 1·9.

We have not thought it worth while to work out the exact figures as to the span, until we have a larger number of observations. At present, therefore, we only record that it was greater than the stature in 66 cases (33 %), equal to it in 18 (9 %), and less than it in 116 (58 %).

IV.—Weight.—The following table shows the number at each age below each half-stone.

	St.	lb.	14	15	16	17	18
Below	5	7	2	1	1	—	—
,,	6	0	2	2	—	—	—
,,	6	7	10	8	7	1	—
,,	7	0	17	11	11	1	4
,,	7	7	10	13	6	2	4
,,	8	0	6	10	13	8	2
,,	8	7	2	5	7	5	1
,,	9	0	1	1	3	2	1
,,	9	7	—	1	3	—	—
,,	10	0	2	2	2	2	1
,,	10	7	—	—	—	1	—
Totals			50	54	53	22	13

For the reasons mentioned above, we contrast the heights also with the averages for the Boston school-girl. In this division

it will be seen that the advantage lies at every age with the American girl, who is consequently, age for age, as far as these fignres go and the two cities are concerned, shorter and stouter than her English cousin.

Boston Girls. Av. Weight. St. lb.	at	Birmingham Girls. No. below this Average.	No. above it.
7 0	14 years.	31	19
7 8	15 ,,	35	19
8 0	16 ,,	38	15
8 3	17 ,,	12	10
8 3	18 ,,	10	3

V.—Vision.—As tested by Snellen's test-types, the vision was normal in 140 cases or 70 per cent. It was defective in one eye and normal in the other in 18 cases or 9 per cent., and defective in both in 42 cases or 21 per cent.

VI.—Hearing.—As examined by the watch test, hearing was normal in 120 cases out of 126 investigated. Of the remaining six the defect, which was never serious in its extent, was unilateral in four instances and bilateral in two.

VII.—Sense Reaction.—The following shows the time (in 100ths of a second) of reaction to sight and sound as tested by Galton's instrument.

100 ths of Second.	Sight.	Sound.
6	—	1
7	—	5
8	—	6
9	1	8
10	1	7
11	2	11
12	3	17
13	1	9
14	12	13
15	18	12
16	16	2
17	13	1
18	7	—
19	5	—
20	8	1
21	2	—

22	...	...	3	...	...	—
23	...	...	—	...	...	—
24	...	...	1	...	...	2
25	...	...	1	...	...	—
26	...	...	—	...	...	—
27	...	...	—	...	...	—
28	...	...	—	...	...	—
29	...	...	—	...	...	—
30	...	...	1	...	...	—

The average for the 95 cases investigated was for Sight 16·5 and for Sound 12·1. In only three cases was the sight reaction more rapid than the sound. It should be mentioned that the recorded figure was in each instance the best of three consecutive attempts, and as it was the first time that any of the girls had seen the instrument, it may be taken for granted that practice had not improved the record in any case.

V.—*Some Methods of Measuring the Temperature of the Sun.*

By P. L. Gray, B.Sc., A.R.C.S.

There is probably no question in cosmical physics which has had such widely different answers as that which forms the subject of the present paper. And, indeed, without limitations the expression "temperature of the sun" is meaningless, as Young and others have pointed out, for a body which must necessarily be at different temperatures in different parts cannot be said properly to have "a" temperature; the earth presents an example of such a condition. The inquiry is limited, therefore (at least primarily), to this question—At what temperature must a body be, of the same dimensions, and in the same position, as the sun, and having a surface of unit emissive power, which would send us the same amount of heat as we actually receive on the earth from the sun?

The answer to this question is called the "*effective temperature*" of the sun, and its determination is beset with a considerable number of difficulties.

Mere comparisons of the heat received from the sun, and that given off by the surface of some substance, here on the earth, at a high temperature, are not very difficult to make, but the deductions to be drawn from such experiments are by no means obvious, and it is here that the difficulties arise. For instance, take the following old experiment of Ericsson's: He floated a fire-brick raft on the

surface of molten iron; on the raft was a calorimeter containing about ten pounds of water; from the rise of temperature of this water he found approximately the amount of heat radiated per second, from each unit of surface of the molten metal; this he could compare with that received from the sun with a moderate degree of accuracy. But this left him still nearly as far as ever from a knowledge of the temperature of the latter, for notice what would be required to determine this:

1st, a knowledge of the temperature of the molten metal—a value only vaguely estimated.

2nd, a knowledge of the emissive power of the metal compared with that of lamp-black.

3rd, a knowledge of the amount of heat absorbed in our atmosphere.

4th, and by far the most important, a knowledge of the law connecting the radiation from a body with its temperature.

Let us take the last consideration first, this being the chief factor in the problem. That this is so, will be seen from the fact that deductions from experiments similar to that of Ericsson's have given results ranging from 1500°C to five or even seven million, according as one or another "law" has been employed. The very low values have been given by employing Dulong and Petit's law, $R = ma^t$, where R is the radiation, m and a some constants, and t the temperature of the body. This law is only proved to hold between very near limits of temperature, and has been proved quite inapplicable to wider limits. Besides, the value given by it for the effective solar temperature is less than that obtainable in the focus of a very large lens concentrating sun-heat, and therefore *a fortiori*, less than that of the sun, even if the effective were equal to the absolute temperature. It is also lower than the melting-point of platinum, the *vapour* of which probably occurs in the sun.

The extremely high values were obtained by an unwarrantable use of Newton's formula, $R = a(T - T_o)$, in which the radiation of a body is taken as simply proportional to the excess of its temper-

ature above that of its surroundings. This law, also, is only applicable within narrow limits, and its use is inadmissible beyond them.

Efforts to find an approximately true expression for the relation between radiation and temperature, the latter being taken within the widest possible limits, have been systematically made only within comparatively recent years, and it is therefore only recently that an approximation, with any pretensions to be seriously regarded, has been possible, on the point which forms the subject of the present paper. Three tolerably complete attempts have been made to solve the problem, the first by Rossetti, in Italy (1879),* the second by Le Chatelier, in France (1892),† and the third by Wilson and Gray, in Ireland (1893)‡. Of these the first and third are more similar in principle, than the second to either.

The first essential is to obtain and measure the radiation from some surface at temperatures up to the highest possible, then to compare the radiation from the sun with that from the surface at some known temperature, and if it is found—as a matter of fact it *is* found—that for equal apparent areas, the sun is radiating more powerfully than the experimental substance, the law of radiation deduced from the experiments must be "stretched" until the required point is reached. So that after all, an extrapolation is required; where then lies the superiority of the new work over the old? It lies simply in the difference in the amounts by which the various formulæ have to be "stretched."

It is evidently more legitimate to extend a relation proved to hold between 300°C and 1500°C, up to a temperature of 7000°C, than to perform a similar process with a formula holding between 30° and 70° say, up to any number of millions. Which is practically the state of the case, so far as the Newtonian formula is concerned.

Rossetti, and Wilson and Gray, used in their experiments the whole of the radiation measured as heat, while Le Chatelier used

* Phil. Mag., 1859, 5th Ser., vol. iii, pp. 324, 438, 537.

† Comptes Rendus, 1892, vol. cxiv, p. 737.

‡ Phil. Trans., 1894.

an approximately simple radiation (i. e., nearly monochromatic), viz., that transmitted by a certain piece of red glass, working therefore photometrically.

We will first consider shortly Rossetti's method and results.

His sources of heat were discs of platinum and other metals which he heated in various ways—in spirit-lamps, bunsen-flames, &c.; estimating the higher temperatures by assuming that the specific heat of the metals remained constant beyond the limits for which it had been determined. The radiation from the hot metal fell on the face of a thermo-pile and the deflections on the scale of a galvanometer connected therewith gave comparative values of the radiation at different temperatures. From these results a "law of radiation" was obtained, the empirical expression for which is $R = aT^2(T - \theta) - b(T - \theta)$, a parabolic formula which for very high temperatures becomes practically $R \propto T^3$.

The law of radiation having been determined, the heat of the sun was allowed to fall on the thermo-pile; the resulting galvanometer-deflection gave a number proportional to the radiation, and this, by insertion in the above formula, gave the required temperature, other correcting factors being allowed for.

The chief source of weakness in this determination was the estimation of the temperature, which probably explains the difference between Rossetti's radiation-law and that of most other experimenters. To this point I shall recur later.

Le Chatelier's experiments may be shortly described thus:

The light from glowing solid bodies, at temperatures estimated from thermo-electric junctions placed in contact with them, was passed through red glass—approximately monochromatic—so that radiation of nearly simple or single wave-length was obtained. The intensity of this red light was measured relatively to a certain standard, at different temperatures up to 1800°C, and an empirical law was obtained, expressing with close accuracy the experimental results. The light of the sun was afterwards passed through the same red glass, and the luminous intensity determined in the same way. Corrections having been made, as in the other cases, for atmospheric absorption, &c., the solar temperature was estimated

by extra-polation in the empirical formula, and a result was arrived at in very satisfactory agreement with that obtained in the next investigation.

The source of heat in Wilson and Gray's experiments was a strip of very thin platinum, which could be brought to any desired temperature by means of an electric current passing through a variable resistance. The principle by which the temperature of the strip can be ascertained has been used by Joly* for determining the melting-points of minerals; in his original instrument, the strip lay horizontally; one end was fixed; the other was held in a movable jaw, capable of rotation round an axis; the strip was kept always taut by means of a small spring attached to the axis of rotation, and the amount of linear expansion, due to the heating of the strip by the current, was measured by a micrometer-screw arrangement. So far there is nothing new in the method, but in the actual calibration of the strip a departure is made which enables the temperature to be known with a high degree of accuracy, and without any calculation, depending only on the determination of the melting-points of three or four substances which have been found by careful experiments by other workers (Carnelley and Violle especially). Argentic chloride (AgCl) melts, e.g., at 451°C; a minute fragment is laid on the platinum strip and watched through a microscope, while the temperature of the slip is slowly raised; suddenly the fragment of AgCl melts, and this may be assumed to happen when the metal on which it rests is also at 451°; the corresponding reading of the expansion-indicating apparatus is taken, and a similar process gone through with a few other substances, including gold, which melts at 1045° according to Violle and 1037° according to Callendar; 1041°, the mean, cannot be far from the truth, and is the value adopted by Wilson and Gray.

A curve giving the relation between the expansion of the strip and its temperature is drawn, and when an optical method is adopted, by means of which the expansion due to a rise of 1° can easily be noticed, the temperature of the strip at any moment is

* Proc. R.I.A., 1891, 3rd Ser., vol. ii, p. 38.

known with a very high order of accuracy, up to 1500°C, about.

To obtain the "law of radiation," the heat from the strip was allowed to fall on a Boys's radio-micrometer, and the comparative values of the radiation obtained at definite temperatures up to 1500°C. The final curve, given by numerous experiments, could be most accurately expressed by means of a simple 4th-power law (at least for temperatures above 400° or 500°), so that if T = absolute temperature of the radiating surface, and R = radiation leaving per unit area, then $R = aT^4$.

This particular law of radiation has been the subject of much discussion; Stefan proposed, and strongly supported, it—but applied it to the radiation of an ideal black surface; Boltzmann upholds it on theoretical grounds, and it has been confirmed by a few other workers. But whether it represents a general law, or not, it certainly represented with great accuracy the experiments of Wilson and myself, and we had no other course open than to adopt it as applying to the particular kind of surface—viz., that of bright platinum—which we were actually using.

The essential principle of our investigation lay in *balancing* the heat received from the sun, against that from a certain area of

A, A′, Receiving surfaces.

B, B′, Bars of alloy.

C, Copper-wire circuit.

our incandescent platinum at a known high temperature. The balancing instrument was a modified form of the radio-micrometer, containing two pairs of alloy-bars, and two receiving-surfaces (instead

of the ordinary one), both connected with the same circuit, and so arranged that heat falling on A tended to produce an opposite rotation to that produced by heat falling on A′. Equal quantities of radiation, therefore, falling at the same time on A and A′ respectively, produced no motion, and thus all the advantages of a null-method were obtained, with the extreme sensibility for which the instrument is famous.

We had then only to make the apparent area of our "artificial sun" great enough, compared with that of the real sun, for the heat from the one to balance that from the other. If the areas were found to be the same, then (leaving out of consideration for the moment atmospheric absorption and other disturbing factors) the two temperatures would be equal, but as a matter of fact it is found necessary, even with the platinum only two or three hundred degrees below its melting-point, to give it an apparent area nearly one hundred times greater than that of the sun before a balance can be obtained.

Again, suppose that none of the already mentioned disturbing elements existed, and that direct radiation from the sun balanced that from the platinum when the latter had a temperature of, say, 1300°C, and an apparent area (as seen from the receiving-surface of the radio-micrometer) five hundred times that of the solar disc. By our 4th-power law we should then have the effective solar temperature $= 1600 \times \sqrt[4]{500}$ approximately $= 7500°$ absolute. This is not an actual case, but it is sufficiently near to represent the principle involved, and the kind of result obtained.

The one serious disadvantage in the use of the radio-micrometer, as compared with a thermo-pile, or a bolometer, is that radiation must fall on it in a horizontal beam, as of course the circuit must hang vertically on its suspending fibre, and in a fixed position; we had therefore to deflect the sunlight on to it from the plain glass mirror of a heliostat, and calculate from the angle of incidence, the amount of energy reflected therefrom in any particular experiment. This amount was calculated from Fresnel's formula, which, strictly speaking, applies only to light, but the possible error thereby introduced does not exceed, as Lord Rayleigh has pointed out, at the most 1 or 2 %.

Next in importance to the Radiation law, comes the question of the amount of absorption of energy in the terrestrial atmosphere. This presents us with a curious example of how the best authorities may for many years all agree—and all be wrong. The value universally accepted, until comparatively recently, for the zenith-absorption, was about 20 %—i. e., for a body in the zenith, 20 % of its heat or light would be absorbed in our atmosphere, and 80 % would reach the surface of the earth, the law of absorption being given by $q = ab^e$.

Where q = the observed intensity of radiation.

a = the intensity of radiation on unit surface outside the limits of the atmosphere.

b = a "constant," which is the fraction of the total radiation absorbed, in the case of a body in the zenith: i. e., it is the absorption-co-efficient."

and e = the thickness of atmosphere traversed by the radiation in the case of a body at any altitude, the value being taken = 1 for a body in the zenith. Up to a Zenith-Distance of 65°, e is practically equal to sec. Z.D.

In the case of the sun, a becomes the "solar constant"—i. e., the number of units of heat (calories) falling on 1 sq. centim. just outside the earth's atmosphere. The mistake made by all the older observers lay in assuming that b was a constant, and that therefore, after finding q for values of e greater than Q, one could reckon back to the values of a and b. Rossetti was one of the first to recognise the fact that b is *not* a constant, and obtained a value of about 30 % as representing zenith-absorption. Even this is probably too small, and Langley* in his great work—"Researches on Solar Heat, &c.," has shown that the law of absorption is by no means so simple as that given above, but that radiation of each wave-length has its *own individual co-efficient of absorption*, and that 40 % is probably nearer the real value.

More recently still Angström† (in 1890) has shown, that

* Professional Papers of the Signal Service, Washington, 1894, and Phil. Mag., 1884, vol. xviii, p. 289.

† Wied Ann., 1890, vol. xxxix, p. 309.

the effect of carbonic acid gas in our atmosphere is probably to increase still further the estimate of the amount of absorption, making it as high as 64 % for a body in the zenith. The expression he obtains for the intensity of the solar radiation outside our atmosphere has the form $i = a_1 b^e_1 + a_2 b_2$, or numerically $i = 1{\cdot}56 \times (0{\cdot}786)^e + 2{\cdot}45 \times (01{\cdot}34)^e$, in which the first term expresses the comparatively weak absorption due to the oxygen and nitrogen of the air, and the second the strong absorption due chiefly to CO_2. The importance of this second term evidently diminishes with comparative quickness, but for values of e near 1 (i. e., for bodies not far from the zenith), it produces considerably more than half of the total effect.

The physical interpretation of this striking result is, that only a small amount of CO_2 will absorb a large amount of radiation between certain wave-lengths, and that which is not absorbed in this "first thickness" is very little affected by subsequent transmission through greater thicknesses. This conclusion has lately received strong independent support from some investigations of Paschen, referred to again later on (p. 114).

Angström's case is a strong one; we shall see presently to what extent these very different values affect the main point under discussion. In this connection it may be well to point out that Le Chatelier's work is concerned in a much smaller degree with these uncertainties than is that of Rossetti, or that of Wilson and Gray, for as he dealt with an approximately simple, monochromatic radiation, in the visible spectrum, his absorption-coefficient might be considered constant, and unaffected by the presence of CO_2 in the atmosphere, the chief absorption due to this being in the infra-red part of the spectrum.

Having briefly glanced at the two chief factors in the determination of our problem, we may pass to minor points which have to be allowed for. Of these, we may mention first the emissive power of the platinum-surface used in Wilson and Gray's researches. This being in its ordinary bare and bright condition, emitted less radiation at a given temperature than it would have, had it been covered with an "ideal-black" substance. A correction from the

same cause had to be made by Rossetti, and he gives, as the result of careful experiments, for the ratio of the emissivity of bare platinum to that of a black surface 35:100. This value, confirmed by experiments of Schleiermacher, among others, was adopted by us, as with our arrangements, original investigation on the point was not convenient, and a considerable percentage of error might be allowed, without producing any important effect in the final result, owing to the fact that the law of radiation would reduce the correction in the proportion of the 4th-root.

The last correcting-factor arises from the reflection from the plain glass mirror of the heliostat; the method of obtaining this has been already described (p. 109).

Let us now take a typical observation, working out the result from it as an example of the use of the various corrections detailed above:

Date: Sep. 4th, 1895.

Sun's declination = 7°.1 N.

„ semi-diameter = 15'.9.

Local time 10h. 4m. ∴ Sun's altitude = 41°.8.

Hence ratio of apparent areas of platinum and sun = 78·71 (from this and other data it is unnecessary to give now).

Temperature of platinum at balancing-point = 1514° absolute.

Absorption in atmosphere (by Rossetti's results) = 36 %.

∴ transmission = 64 %.

Angle of incidence of sunlight on mirror of heliostat = 61°.

∴ amount of heat reflected = 9·5 %.

Ratio of emissivity of platinum and lamp-black = $\frac{35}{100}$.

The radiation from the sun, just outside the earth's atmosphere is therefore $78{\cdot}71 \times \frac{100}{64} \times \frac{100}{9{\cdot}5} \times \frac{35}{100} = 453{\cdot}1$ times that from the platinum at a temperature of 1514° abs.

The effective temperature of the sun, by this single observation, therefore comes out as $1514 \times \sqrt[4]{453{\cdot}1} = 1514 \times 4{\cdot}614 = 6935$ abs. This value is higher than our final result, because when the two sources of heat—sun and platinum—were reversed, so far as the two receiving surfaces of the radio-micrometer circuit were concerned, a lower temperature was found sufficient to produce balance

—a result which was to be expected, since no particular care had been taken to procure equality in this respect.

The final mean, of about one hundred separate observations, gave a resulting effective temperature of about 6200°C, but it must be remembered that this was obtained by using Rossetti's results in terrestrial atmospheric absorption; if we use Langley's we obtain approximately 6500°; and if Angström's* about 7500°—a result in curious agreement with Le Chatelier's 7600°, and somewhat lower than Rossetti's, which is nearly 10000°—but in this latter case the law of radiation is quite sufficient to account for the difference; with his experimental results, and our law of radiation (and *vice versâ*), the two final estimates come out nearly exactly the same.

Summing up, I think it will now be agreed that the effective temperature of the sun cannot be very far from 8000°C; i. e., that it is probably not so much as 1000° different from this, and though future investigations in terrestrial atmospheric absorption may tend slightly to raise the estimate, yet, considering the effect of such an immense difference as that given respectively by Rossetti's and Angström's conclusions on this point of absorption, it is hardly likely that newer work will seriously alter the final value.

The question as to the amount of absorption in the sun's own atmosphere leads us outside that of the "effective" temperature, and to discuss it at any length would make the present paper too long. It may, however, be briefly noted, that by using certain results, experimental and theoretical, of Wilson and Rambaut,* the radiation from the sun would become twice as great as it is at present, if the solar atmosphere were removed; our estimate of its effective temperature would therefore have to be multiplied by $\sqrt[4]{2} = 1{\cdot}2$ approximately, and our 7500° would become about 9000°.

In conclusion, a few words as to the physical meaning of this "effective" temperature, and as to the probability of its representing anything like the actual temperature of the superficial parts of the body of the sun, may be added, especially as some recent

* Wied Ann., 1890, vol. xxxix, p. 309.

investigations of Paschen have an important bearing on the subject.

Although it is no doubt true, as mentioned at the beginning of this paper, that the sun cannot be said to have "a" temperature, yet we may probably fairly consider that the thin layer known as the chromosphere, and the first few miles of the photosphere, have a mean actual temperature, of which the "effective" temperature may give us some sort of idea. Until recently, it was supposed that a deduction from the one to the other would be quite impossible, as the radiative or emissive power of the glowing substances was quite unknown. But our knowledge as to the radiation from gases has lately received additions which make a discussion of the subject at least possible, Paschen's experiments* on the emission from heated CO_2 being especially important in this connection.

Carbonic acid gas, raised to a high temperature, has a very broad emission "band" in the infra-red, and the intensity of the energy radiated, at the top of the corresponding emission-curve Paschen finds to be *exactly equal to that at the same point in the energy-spectrum of a solid black surface* at the same temperature, with only a very small mass and thickness of the gas. Also it is well known that the emission-band of any gas broadens as the pressure increases. Putting these facts together, it seems therefore not at all likely that the surface of the sun, consisting largely of incandescent gases under enormous pressures, may give a spectrum which in all parts of its energy-curve may reach the same amount as that from a black solid, supposing that this latter could be raised to the same high temperature without changing its properties. But this is only another way of saying that the emissive-power of the surface (by which we should mean a thickness of some miles) may be equal to unity. Le Chatelier, in his paper already quoted, speaks of this as being very probable, but he does not state the grounds on which he founds his opinion.

And if we imagine that any parts of the intensely bright surface are still solid, it is still not impossible that the same condition may hold. A certain amount of confirmation for such an

* Wied Ann., vol. li, 1894, p. 1.

idea may be found in the experimental fact that as the temperature of a bare platinum-surface is raised, its emissive power does actually become nearer to unity, the ratio of "bright" to "black" increasing from about ·2 at 300°C to ·35 at 1500°C. The reason of this must lie in some alteration of the physical state of the surface, and it is therefore conceivable that at very much higher temperatures the difference may be still further diminished, and may even finally disappear altogether. This conclusion, I admit, is at present chiefly theoretical, and too much stress must not be laid on it. But that the possibility exists must, I think, be admitted.

Finally, therefore, we may say, that the effective temperature of the sun is not very far from 8000°C, and that the actual mean temperature of its superficial layers may also be of the same order of magnitude.

VI.—*A Bibliography of Midland Glaciology.*

By W. Jerome Harrison, F.G.S.

In dealing with the Bibliography of Midland Glaciology it is absolutely necessary to consider—though as briefly as possible—much that has been done outside the limits of the special district to which this paper refers. For the science of Glaciology neither had its origin in the English Midlands, nor has it received from dwellers therein—with a few exceptions—contributions equal in importance to those which have been furnished by students living in regions where the glacial phenomena are more obvious, and more easily deciphered. For the midland counties of England form a part of the (glacially) dubious region which my regretted friend the late Carvill Lewis denominated the "fringe." More than one glacier here terminated its southward course; and the torrents resulting from the normal melting of the glacier tips, and from the final and complete melting of these great bodies of ice have interfered greatly with the glacial moraines and with other evidences of glacial action in the district.

North of the parallel of 50° in Europe and of 39° in North America, surface accumulations of clay, sand, and gravel, with numerous blocks of rocks different in nature to the subjacent strata, are of frequent, nay of continual occurrence. In thickness these loose and mostly unstratified beds may vary from a few inches to

some hundreds of feet; and they are evidently altogether different both in nature and in origin from the stratified rocks upon whose edges they repose.

Remarkable as are the appearances presented by these strange masses of rock, they appear to have attracted little or no attention until the eighteenth century, when we find numerous writers on the Continent assigning them to gigantic floods (*débâcles*) when great ocean waves swept over the land. In our own country Dean Buckland wrote an able book (the *Reliquæ Diluvianæ*) in support of a very similar theory, in 1823, in which he assigns the formation of the beds in question to the Noachian Deluge. It was at this time that the term "Diluvium" was first applied to these supposed relics of the Flood, and it long remained in use.

But the angularity and the great size of many of the rocks in question, as compared with the long distances they must have travelled, soon caused a disbelief in the agency of water as the mode of transport to spring up.

Following several minor suggesters of ice in this form, Lyell brought forward strong arguments in favour of icebergs in 1830; and he was supported by Charles Darwin in 1839. In 1840 Lyell introduced the term "Drift" for what had previously been called "Diluvium." The new name certainly expressed the fact that the materials referred to had "drifted" from their native spots. Indeed the iceberg theory of Lyell has still many adherents.

It was very natural that the scientists of a glacier-ridden country should be the first to argue in favour of "rivers of ice." In Switzerland, Venetz in 1822 was followed by Charpentier in 1835, and by Agassiz in 1837, in urging that all the phenomena of the "Diluvium" or the "Drift" could be explained by a former great extension of the glaciers. Agassiz came to England in 1840, and he soon discovered here all the traces of glaciers—*roches mouonnées*, moraines, etc.—with which he was so familiar on the Continent. Buckland was his first convert; and since then the "glacial theory" has received powerful support from such experts as Ramsay, the brothers Geikie, Goodchild, Tiddeman, Searles Wood, jun., and a host of others.

Turning more directly to my subject—*The Bibliography of Midland Glaciology*—it is not my intention to refer in this paper to any views of my own; but rather to endeavour to place upon record in an accessible form, all that has hitherto been accomplished. The lack of a bibliography of papers treating of Midland Glaciology has been, I believe, one of the great reasons for the slow progress which has been made. Each worker has had to search out for himself all that had already been done; or has perhaps set to work without a guide of any kind; and so the task has been retarded or has been done over and over again.

Dating from the year 1811 up to the present day, I am able to record the titles of more than one hundred and fifty papers written especially upon the glacial phenomena of the Midland Counties. For the complete understanding of these local papers it is necessary to know what has been done within similar limits of time in other parts of the British Isles. I have therefore added the titles of over one hundred other books and papers, which, taken together with those previously enumerated, will, I hope, enable the students of Midland Glaciology to obtain readily both a local and a general knowledge of the literature and bearings of the subject.

It has been said that we "only see what we look for;" so that "knowing what to look for" is half the battle. Equipped with the knowledge accumulated by our predecessors we have the immense advantage of being able to begin where they left off.

1811.—Aikin, A. Observations on the Wrekin, and on the great Coalfield of Shropshire.—*Trans. Geol. Soc.*, pp. 190-212.

P. 192. Describing the red sandstone (Trias) the author remarks—"Rolled stones of quartz, of granite, of greenstone-porphyry, and of other primitive rocks, are found dispersed over its surface and embedded in the loose sand, but are rarely, if ever, observed at any considerable depth in the solid rock."

1821.—Buckland, Rev. W. Description of the Quartz Rock of the Lickey Hill, &c.; with considerations on the evidences of a recent deluge afforded by the gravel beds of Warwickshire, &c.—*Trans. Geol. Soc.*, pp. 506-544.

P. 518. South-east of Shipston-on-Stour (Warwickshire) pebbles of hard red chalk occur "like that of the Lincolnshire Wolds, and others of hard white chalk." The quartzose gravels are traced southwards to Oxford.

1823.—Buckland, Rev. W.—*Reliquiæ Diluvianæ;* 4to., pp. 278 with plates.

The first 164 pages of this classical work describe the contents, etc., of several caves in England and in Germany. The remainder of the book is occupied with descriptions of "diluvial action" in various countries, "attesting the action of an Universal Deluge."

"Norwegian pebbles" are mentioned (p. 193) as occurring at Bridlington. The Midland gravels are described (pp. 195-199, and 249-258). Shap granite occurs at Darlington, in the bed of the Tees at Barnard Castle, and near the highest points of the pass at Stainmoor Forest (p. 194). The [Great Chalky Boulder] clay at Chellaston is mentioned (p. 195.) Criffel granite has crossed the Solway Firth to Cumberland; while granite from "Ravenglass, on the west of Cumberland," lies in masses of some tons weight on the west of the towns of Macclesfield and Stafford, and between Dudley and Bridgnorth. All these boulders, pebbles, etc., were drifted (whence the name "Drift") from N. to S. by strong currents.

"Plate XXVII" is a map "showing the manner in which the Lickey sandstone pebbles have been drifted from Warwickshire through two low points in the escarpment of the oolite limestone at Moreton-in-Marsh, and on the north of Banbury; and been spread over the country along the valleys of the Evenlode, the Cherwell, and the Thames, and also in the north of Buckingham."

1825.—Grimes, Edward, R.N. "Observations on the Flints of Warwickshire." — *Edin. Journ. Science*, vol. III, pp. 77-80.

"I observed these flints first at Churchover in Warwickshire, but have since traced them from about ten miles north of Leicester to the village of Brandon about ten miles south of Rugby, comprising a distance of about forty miles north and south; also to about fourteen miles eastward of Churchover, towards Northampton. In the direction of Coventry they do not appear to extend beyond Brandon, where the style of the gravel alters. They are the common chalk-flint, and are found in the gravel and in ploughed fields.

1831.—Jukes, Fred. "Observations on the Diluvial Gravel in the neighbourhood of Birmingham." — *Magazine of Natural History*, vol. IV, pp. 372-377.

The new canal from Birmingham to Wolverhampton was made through a very deep bed of sand and gravel near Smethwick. It contained a "vast accumulation of detached rocks of almost every description." Large rounded blocks of basalt (from the Rowley Hills) and of ironstone (from Coseley Hill) were abundant; with "granite, porphyry, &c." No bones were found, though the excavation was in some places nearly 100 feet deep. Thirteen figures of fossils found in the boulders are given, nine of which appear to be plants from the Coal measures. The upper surfaee of this gravel is in some places covered with finely contorted sands, 20 or 30 feet in thickness. Flints occur, but the Gryphæas and the granite so abundant in the gravel pits at Newport, in Shropshire, are absent here.

1834.—Strickland, H. E. On the occurrence of Fresh-water Shells of existing species beneath the gravels near Cropthorne, in Worcestershire.—*Proc. Geol. Soc.*, vol. II, pp. 95, 111.

The deposit is situated "on the road from Evesham to Pershore, and on the east side of the small rivulet which flows from Bredon Hill towards the Avon." Chalk flints occurred, with bones of Hippopotamus, &c.

1835.—Trimmer, Joshua. On the occurrence near Shrewsbury of Marine Shells of existing species in transported gravel and sand resting upon a peat bog which contains embedded trees.—*Proc. Geol. Soc.*, vol. II, p. 200. (The volume is dated 1838.)

The section was exposed in widening the road about five miles from Shrewsbury towards Shiffnal. Assigns the section to "a rush of the sea."

1836.—Murchison, Sir R. On the Gravel and Alluvia of South Wales, and Siluria, as distinguished from a Northern Drift covering Lancashire, Cheshire, North Salop, and parts of Worcester and Gloucester.—*Proc. Geol. Soc.*, vol. II, pp. 230-233. (Volume bears date 1838.)

All the drift in South Salop, Hereford, &c., is of local origin. The boulders of northern origin occur in vast numbers between Wolverhampton and Bridgnorth, from which latitude they begin to diminish in size; but coarse gravel, composed of the same materials, is prolonged southwards like the tail of a delta through Worcestershire, until it dies away in the fine silt and gravel of the Vale of Gloucester. Not a fragment of any such (northern) detritus enters the region of Welsh and Silurian drift; but in the environs of Shrewsbury certain mounds of the latter are capped by clay and boulders of the northern drift, which is thereby shown to be of subsequent formation.

Marine shells were traced over a wide area in Shropshire. At Norton (Mr. Trimmer's section), near Shrewsbury, large boulders occur at considerable depths. The "trees" here were not in situ.

Considers possibility of transport of boulders by marine currents, ice-floes, &c.; but doubts if any complete explanation of their mode of transport has as yet been given.

1839.—Murchison, Sir R. I. The Silurian System, with descriptions of the Coalfields and overlying formations.—Two vols. John Murray, London.

Chap. XXXVII: pp. 509-523, Superficial Detritus.

Chap. XXXVIII: The Northern Drift, pp. 523-535.

Chap. XXXIX: Northern Drift (continued), pp. 535-548.

Chap. XL: Superficial Deposits (continued), pp. 548-558.

Chap. XLI: Superficial Deposits (concluded), pp. 558-568.

Woodcuts.—No. 107, section of gravel and sand near Shrewsbury; No. 108, ditto, with sea shells.

Five miles west of Birmingham the "Grand Junction railroad" cutting shows 25 to 30 feet of foxy-coloured sand and pebbles, resting on 60 to 70 feet of bluish clay, with local debris; underneath which is (irregular) sand like that on top.

No drift is found beyond (to the south of) the Breidden Hills and Wenlock Edge. The fine gravel near Wellington contains abundant shells, and sea-shells occur at many places. Boulders are most numerous between Bridgnorth and Wolverhampton.

Attributes the drift to sea-currents rushing from north to south during a period of submergence.

1840.—Allies, Jabez. On Marine Shells found in Gravel at Worcester. — *Brit. Assoc. Report* (of Birmingham Meeting in 1839), p. 70.

"Mr. Allies exhibited a series of the Marine Shells of existing species which have been found in the gravel near Worcester since the publication of Mr. Murchison's Silurian System, in which work their occurrence, in this locality, is first noticed. At Bromwich Hill, on the west of Worcester, rolled shells of *Turritella ungulina* and *Cardium edule* have been found beneath 12 feet of gravel at about 50 feet above the Severn. Bones and teeth of the elephant and rhinoceros occur in the same bed of gravel. At Kempsey, four miles south of Worcester, the *Turbo littoreus* has been found (in addition to the shells enumerated by Mr. Murchison at p. 533 of his work, beneath about 12 feet of gravel, from 15 to 20 feet above the Severn,"

1842.—Darwin, Chas. Notes on the Effects produced by the Ancient Glaciers of Carnarvonshire, and on the Boulders transported by Floating Ice.—*Edin. New Phil. Journal*, vol. XXXIII, pp. 352-363. (Also in *Phil. Mag.*, vol. XXI.)

Mentions in a note (p. 360) that—"On the summit of Ashley Heath, in Staffordshire, there is an angular block of syenitic greenstone, four-and-a-half feet by four feet square, and two feet in thickness. This point is 803 feet above the level of the sea. From this fact, together with those relating to Moel Tryfaen and Faban, we must, I think, conclude that the whole of this part of England was, at the period of the floating ice, deeply submerged. . . The boulder on Ashley Heath probably has been exposed to atmospheric disintegration for a longer period than any other in this part of England. I was, therefore, interested in comparing the state of its lower surface, which was buried two feet deep in compact ferruginous sand (containing only quartz pebbles from the subjacent new red sandstone), with the upper part. I could not, however, perceive the smallest difference in the preservation of the sharp outlines of its sides. I had a hole dug under another large boulder of dark-green felspathic slaty rock, lying at a lower level; it was separated by 18 inches of sand (containing two pebbles of granite, and some angular and rounded masses of new red sandstone) from the surface of the new red sandstone. One of the rounded balls of this latter stone had been split in two, and deeply scored, evidently by the stranding of the boulder."

In another note on p. 358, Mr. Darwin writes—"I may mention, that at Little Madeley, in Staffordshire, I have found chalk flints in the gravel beds associated with existing species of sea-shells."

1842.—Ick, W. On some Superficial Deposits near Birmingham.—*Proc. Geol. Soc.*, vol. III, pp. 731-732.

Describes section exposed by "New Junction Canal at Saltley, a mile-and-a half north-east of Birmingham." Peat-bed two feet thick, with prostrate trunks of oak, hazel, &c., and horns of stag and ox.

1842.—Strickland, H. E. Memoir descriptive of a series of coloured sections of the cuttings on the Birmingham and Gloucester Railway.—*Trans. Geol. Soc.*, second series, vol. VI, pp. 545-555; with plate of sections.

Page 553—"Chalk flints, though not absolutely wanting in the Birmingham gravel, are yet so extremely rare as to prove that the current which transported it came from the north and not from the east."

"At Moseley the railway is cut through a vast deposit of this gravel, upwards of 80 feet thick, reposing upon red marl." A stratum of sand, about 30 feet thick, free from pebbles, occurs in the middle of the (Moseley) gravel. The extreme height which this (northern) gravel attains on the line of the railway is 544 feet above sea level.

1844.—Garner, Robt. Natural History of the County of Stafford, pp. VIII and 550; with plates and map. Supplement of 60 pp. published in 1860. Van Voorst, London.

Drift described pp. 199-202. Boulders numerous at Trysull, Sheriff Hales, &c. Bivalve shells found by Darwin at Little Madeley, and by the author "in the gravel pit between Great and Little Madeley."

Appendix, p. 38—"Jaspery chalk flints appear to be common in the drift at Needwood, and ananchytes of a similar origin are picked up. Lias fossils, as ammonites, nautili, and *Gryphaea incurva*, have been found in the south-east part of the county, about Codsall and Wolverhampton, on digging below the surface."

1845.—Byres, R. W. On the Traces of the action of Glaciers at Porth-Treiddyn, Carnarvonshire.—*Quart. Journ. Geol. Soc.*, pp. 153-155.

Quotes a note by Buckland on striae near Port Aberglaslyn, &c., and adds several other examples in the neighbourhood.

1848.—Baker, Thos. Practical Survey of Dudley, &c., pp. VIII and 240; map. R. B. Moody and Co., Birmingham.

Page 3—"There is some portion of brick clay in the far greater part of this geological district, and some in the northern side to a considerable depth; but still the same is particularly on the eastern side, much intermingled with the travelled and abraded fragmentary from of *(sic)* the basaltic hills. There are in and about this place thousands of tons drifted from the higher peaks of the main summits, and have filled up some of the parts around the skirts, which were rather swampy, to a very considerable height. These become rather a nuisance in the brickmaking."

1848.—Darwin, C. On the Transportal of Erratic Boulders from a lower to a higher level.—*Quart. Journ. Geol. Soc.*, vol. IV, p. 315.

Gives numerous examples. Ascribes the lifting of the boulders to the action of coast-ice upon an area which was undergoing depression.

1849.—Buckman, Professor J. The Ancient Straits of Malvern, 12mo. London.

1851.—Trimmer, J. Erratics of Norfolk, Kent, &c.—*Quart. Journ. Geol. Soc.*, pp. 19-38.

Refers to the importance of mapping the material which actually forms the surface of this country. "That maps of the surface geology of these islands would be of great utility, must be obvious to everyone who combines agricultural with geological knowledge, and who is aware of the extent to which our country is covered by the the superficial deposits, whether we call

them drifts, erratic tertiaries, or by any other name. Whatever may be the present fate of such maps, it may be safely predicted that another generation will not pass away without seeing the construction of them firmly established as a recognised part of agricultural practice, and sedulously cultivated as an important branch of geological research."

On p. 20 there is an important reference—"On the western coast the northern drift with its marine remains has penetrated in Cefn Cave, and, by its superposition to the deposits containing mammalian remains testifies, like the buried forest, to the presence of a sub-aerial surface immediately before the transport of the northern blocks."

1851.—Trimmer, J. On the Erratic Tertiaries bordering the Penine Chain, and on the scratched detritus of the Till.—*Quart. Journ. Geol. Soc.*, pp. 201-207.

Notes divisions of Boulder-clay, Till, and Sands and Gravels in the drift of Cheshire, &c. Assigns the polishing and grooving of the stones to ice-action—probably coast-ice. Mentions the occurrence of marine shells in several localities.

1852.—Hopkins, J. On the Causes which may have produced Changes in the Earth's Superficial Temperature.—*Quart. Journ. Geol. Soc.*, pp. 56-92.

1855.—Hull, E. On the Physical Geography and Pleistocene Phenomena of the Cotteswold Hills.—*Quart. Journ. Geol. Soc.* pp. 477-496.

Granite is absent. Three boulders of Millstone Grit (the largest, three feet in diameter) occurred at the villages of Bowl and Frescot; near the southern termination of the Vale of Moreton, yellow chalk flints occur; and this drift extends up to 490 feet on Mickleton Hill.

1855.—Ramsay, Sir A. C. On the Occurrence of Angular, Sub-angular, Polished, and Striated Fragments and Boulders in the Permian Breccia of Shropshire, Worcestershire, &c., and on the probable existence of Glaciers and Ice-bergs in the Permian Epoch.—*Quart. Journ. Geol. Soc.*, pp. 185-205.

"Near Wribbenhall in part of the pebble-beds (of Bunter date) there are breccias strikingly resembling those of Permian Strata; and also near Astley, a little S.W. of Stourport, and probably at Alfrick, at the base of the white sandstones there is a recurrence of the same phenomenon. It is possible that these may have been reconstructed from the waste of the older Permian Breccias, but when I examined them I felt more disposed to attribute them to direct glacial action."

The Permian breccias of the Clent Hills, &c., contain angular blocks up to half-a-ton in weight. "Many of them are highly polished, and others are grooved and finely striated." They are embedded in a mass of red marl, which resembles a boulder clay. The author thinks that these breccias were brought by icebergs which broke off from glaciers which then covered the Longmynd and the Shelve country, a distance of about thirty miles west of the Clent Hills.

1856.—Lees, Edwin. Pictures of Nature around the Malvern Hills, pp. 336; illustrated. D. Bogue, London.

Describes the "Severn estuary" from Worcester to Bewdley (p. 254). A sand-pit at Northwick near Worcester abounds with fragments of broken-up shells.

1857.—Lycett, John. The Cotteswold Hills, pp. 170; seven plates. Piper and Co., London.

Chapter XI, pp 112-117 treats of the "Fluviatile, Estuary, and Marine Drifts." The main plateau of the Cotteswolds is destitute of drifts. But where the plateau dips on the north to the Vale of Moreton we get the Northern pebbly drift.

1858.—Jamieson, T. F. On Fossil Shells and Striated Boulders at High Levels in Scotland.—*Quart. Journ. Geol. Soc.*, pp. 509-532.

Thinks that the marine shells indicate submergence to a depth of at least 450 feet.

1858.—Strickland, Hugh E. Memoirs of (including all his published papers), by Sir S. W. Jardine, Bart.; large 8vo., pp. 441, with 23 woodcuts and eight plates. Van Voorst, London.

The papers reprinted in this volume which contain matters of interest to the Midland Glacialist are as follows:—

I.—1835. Memoir on the Geology of the Vale of Evesham, from the *Analyst*, vol. II, p. 317: chalk flints and fossils occur in the gravels.

II.—1835. This paper was written in June, 1835, and was sent to the Geological Society, but (in consequence it appears of the author's absence from England for a lengthened period at this date) it was never read or published. Hence it appears in this book for the first time. The Drift is divided into—*(a)* General; *(b)* Local; and *(c)* Fluviatile. The "General" Drift is again divided into—(1) Quartzose (Northern Drift of Murchison); and (2) Flinty. The Quartzose Drift came from the north; and the Flinty Drift from the east; and "there is no appearance of a transition" between them. The Local Drift lies at the foot of the Oolitic hills of Broadway and Bredon; it is "distinguished by the entire absence of any materials which are foreign to the neighbourhood."

The Fluviatile Drift "appears to be a mixture of the other three kinds." It occurs in patches along the flanks of the Avon, at heights up to 40 feet above the river; it is the only drift which contains organic remains of contemporaneous origin. Bones of mammals and of mollusks occur at Lawford, Shottery, Bengeworth, Charlton, Cropthorne, &c.

As to the origin of the "General Drift" the opinions of Murchison (violent marine currents during a submergence) are adopted. The "Local Drift" is probably an old shingle beach.

III.—1837. On the Nature and Origin of the various kinds of Transported Gravel occurring in England.—*Brit. Assoc. Report of Liverpool Meeting*, p. 61.

This paper is here printed in full for the first time. As an appendix to it we find six "Queries respecting the Gravel in the neighbourhood of Birmingham," which the author had had printed and which he had circulated during the meeting of the British Association in Birmingham in 1839. The paper reiterates the facts and conclusions of No. II (above). The "General" Drift is now termed "Marine" Drift.

IV.—1840-41. Description of the Coloured Sections of Cuttings on the Birmingham and Gloucester Railway.—*Proc. Geol. Soc.*, vol. III, pp. 314, 446.

But for Strickland's premature death at the age of 42—he was killed by a passing train while geologising in a railway-cutting near Retford—there can be no doubt but that he would have added much more to our knowledge of the geology of the Midland Counties.

1859.—Forbes, Jas. D. Theory of Glaciers.—Large 8vo, 278 pp.

An excellent book for the Glaciologist, containing much original work.

1859.—Jukes, J. Beete. Survey Memoir on the South Staffordshire Coalfield; second edition. Drift, pp. 207-208.

Very fine red sand at West Bromwich and Hill Top, in places between Darlaston and Pelsall, and thence towards Willenhall and Pelsall. From Moxley Sand Holes it runs in a quarter-of-a-mile wide band to Marshend a little east of Wednesfield. It fills a valley in the Coal Measures and makes no feature at the surface.

1860.—Hull, E. Geology of the Leicestershire Coalfield and of the Country round Ashby-de-la-Zouch.—*Geol. Survey Memoir.*

The drift is referred to in one paragraph only (p. 67). Coleman's description of it is cited as being divisible into three members:—*(a)* Northern drift-granite; *(b)* Eastern drift with chalk and flints; *(c)* Charnwood drift.

1860.—Ramsay, Sir A. C. The Old Glaciers of Switzerland and North Wales. — 12mo., 116 pp., illustrated; map. Longmans and Co., London.

Very clearly written, and of great interest. The woodcuts are very charming.

1860.—Roberts, Geo. E. The Rocks of Worcestershire; pp. XV, 247; with map. Masters, London. Chap. XIII, pp. 220-233; the Post-tertiary Period.

Two or three large boulders occur at Broom Hill, south of Belbroughton; and at Clent and Holycross. Sand-banks are found near Kidderminster. Marine gravels are not seen south of Hartlebury.

1860.—Tyndall, John. The Glaciers of the Alps.—8vo., 444 pp.; illustrated. J. Murray, London.

Gives a full and interesting account of Glacial Phenomena generally.

1861.—Symonds, Rev. W. S. On some Phenomena connected with the Drifts of the Severn, Avon, Wye, and Usk.—*British Association Report*, pp. 133-134.

Divides the deposits into—(1) Alluvial; (2) The Lake Period; (3) Low-level Drift; (4) High-level Drift.

1862.—Lister, Rev. W. Drift containing Recent Shells near Wolverhampton.—*Quart. Journ. Geol. Soc.*, pp. 159-162.

Unstratified sand and clay at Bushbury Junction gave eight species of marine shells (*Astarte, Nassa,* &c.) with rolled Liassic fossils, flints, &c.

At Oxley Manor (half-mile N.W. of Bushbury) clay, resting on sand, yielded five species of shells.

At Wobaston Big Meadow (one-and-a-half miles north of Bushbury Junction) a gravel mound contained *no* shells.

Similar shells occur "at Mr. Sparrow's Colliery of Portobello."

Mr. Gwyn Jeffreys adds: "all of these shells are much rolled and broken, and they appear to have been cast up by the tide on a pebbly beach. . . . It is possible that these shells may have been carried off with the pebbles from a beach in the Arctic regions by an iceberg, which, after traversing a considerable distance in a glacial sea, may have stranded or melted, and deposited its load in the spot where the shells and pebbles have now been found."

1862.—Ramsay, Sir A. C. The Glacial Origin of Certain Lakes.—*Quart. Journ. Geol. Soc.*, pp. 185-204.

In the period of extremest cold of the Glacial epoch, great part of North America, the north of the Continent of Europe, great part of Britain, Ireland, and the Western Isles, were covered by sheets of true glacier-ice in motion, which moulded the whole surface of the country, and in favourable places scooped out depressions that subsequently became lakes."

1862.—Smith, Jas. (of Jordanhill). Researches in Newer Pliocene and Post-tertiary Geology. — 8vo., 191 pp.; coloured plates.

The author did good work in the Clyde basin, and elsewhere in Scotland.

On p. 152 a letter from H. E. Strickland records the finding of an *Oliva*, "a beautiful specimen, retaining the colour and the gloss," from beneath 12 feet of gravel at Worcester.

1863.—Jamieson, T. F. On the Parallel Roads of Glen Roy, and their place in the history of the Glacial Period.—*Quart. Journ. Geol. Soc.*, pp. 235-259.

The roads are old lake beaches, the lake being formed by the damming up of the mouth of the glen by a glacier.

1864.—Belt T.—On the Formation and Preservation of Lakes by Ice Action.—*Quart. Journ. Geol. Soc.*, pp. 463-465. An abstract only.

Supports Professor Ramsay's theory of the scooping out of many lake-basins by glaciers.

1864.—Hayward, W. H. Mammalian Remains at Churchbridge, near Oldbury.—*Trans. Dudley Geol. Soc.*, pp. 136-138.

"I visited the clay-pit yesterday, and on looking at the cutting from above downwards there appears about seven or eight feet of gravel-drift, then about three feet of yellowish-white marl, and underneath these a deep stratum of bluish clay, and from between these two the specimens were removed." The bones (elephant tusk) were obtained by Mr. Gray and Dr. Cooper. Mr. H. Johnson exhibited an elephant's tooth from the drift, obtained in cutting the Stourbridge Mineral Railway some years ago.

1864.—Maw, Geo. Notes on the Drift-deposits of the Valley of the Severn, in the neighbourhood of Coalbrookdale and Bridgnorth.—*Quart. Journ. Geol. Soc.*, pp. 130-144.

The drift at Strethill is 200 feet thick: 60 feet clean sand at bottom, then 60 feet of mingled beds—gravel, silt, and clay, and 60 more feet of clean sand on top. Flints, lias fossils, Wrekin rocks, Lake district and Scotch granites, &c., occur.

"Of several hundred examples of marine shells, not above six or seven are quite perfect. They are distributed indiscriminately through the whole mass of drift, including the clay and gravel beds. Of that massive and strong shell, *Cyprina Islandica*, I have detected nothing but fragments, scarcely an inch across, and mostly much smaller."

Erratic blocks are numerous and of large size. They were probably brought by icebergs.

1865.—Brodie, Rev. P. B. Remarks on the Drift in part of Warwickshire, and on the Evidence of Glacial Action which it affords.—*Brit. Assoc. Report*, p. 49.

1865.—Browne, Rev. G. F. Ice-caves of France and Switzerland: a Narrative of Subterranean Exploration.—8vo., pp. 315; illustrated. Longmans and Co., London.

The natural ice-caves described have no connection with existing glaciers.

1865.—Startin, A. On the Drift in the Parish of Exhall, north of Coventry. (All *local* rocks and angular quartzites of Hartshill.)—*Brit. Assoc. Report*, p. 74.

1865.—Symonds, Rev. W. S. On Some Ancient Drifts and Old River Beds of Siluria.—*Brit. Assoc. Report*, p. 74.

Thinks that the effect of *land-ice and snow* in transporting boulders has been underestimated. "He attributed the transportation of the masses of subangular gravel which contain large erratics from the Malvern range, and are distributed in patches on the Hanley and Castle Morton Plains, to the effect of a mass of frozen snow and ice, which in former days stretched from the Malverns down to the plains."

1865.—Woodward, C. J. On a deposit near Lilleshall, Salop, containing recent Marine Shells.—*Brit. Assoc. Report:* Proceedings of Sections, p. 79.

Describes a gravel mound 463 feet above sea level at Fox Hill Field, New Lodge Farm, near Lilleshall; ten univalves, eleven bivalves, with *Balanus*, were found. "Lias fossils much waterworn, granite pebbles, and subangular fragments of sandstone, curiously pitted on their surfaces, occur with the shells."

1865.—Woodward, C. J. On a Drift Deposit near Lilleshall, Shropshire, containing recent Marine Shells.—*Geol. Mag.*, pp. 567-568.

Paper read before the British Association. The deposit is situated about three miles from Oakengates Station. The shells occur only on the north side of the mound.

1866.—Brodie Rev. P. B. Drift of a part of Warwickshire.—*Proc. Warwickshire Field Club*, pp. 14-23.

Flints predominate at Haseley, Hatton, and Edstone. The Lias outlier at Brown's Wood, near Wootton Wawen, is covered with Northern Drift, and

a deep gravel pit on the summit of the hill contains some very large boulders. Gives list of rocks found in Drift, and of the fossils they contain.

1866.—Startin, A. The Drift at Exhall, near Coventry.—*Proc. Warwickshire Field Club*, pp. 26-33; with map.

Clay and sand (up to 75 feet in thickness) extends for three miles from Collycroft, just south of Griff Hill, to Foleshill; local boulders of trap, sandstone, &c., were numerous at the bottom of this drift; its breadth does not exceed half-a-mile.

West of this drift, and reaching from Arbury Mill and Bedworth on the north, to past Exhall Church on the south we find angular drift composed, without doubt, of the Hartshill quartzite, &c. This drift does not exceed three or four yards in thickness.

Passing still to the west the drift changes. A ridge of Permian rocks extends from Ansley on the west to Corley on the south. The height at Corley is 625 feet, being 300 feet above Exhall Church. West of this ridge rounded quartzose pebbles are numerous.

Going eastwards we find liassic fossils, common in the country round Bulkington and Wolvey.

Thinks that the boulders were carried by coast ice.

1866.—Whittem, J. S. Supposed Glacial Drift near Coventry.—*Proc. Warwickshire Field Club*, pp. 23-26.

Rounded quartzose pebbles are the commonest rocks in the Drift. Chalk flints turned up while land-draining, on the north side of Coventry.

At Wyken Colliery flints occurred, and in the brick-clay was striated limestone. Below the brick-clay is a bed of sand and gravel.

1867.—Brodie, Rev. P. B. Drift of Warwickshire.—*Quart. Journ. Geol. Soc.*, pp. 208-213.

Flints occur at Haseley, Hatton, and Edstone. The quartzite pebbles are sometimes fossiliferous.

1867.—Maw, G. The Drift Deposits of the Eastern Counties.—*Geol. Mag.*, pp. 276-281.

On p. 279 gives particulars of Drift sections at Strethill, Buildwas, Bridgnorth, Benthall, Broseley, Burton, &c.

1867-94. — Report Rugby School Natural History Society. — Lawrence, High Street, Rugby; 1/- per part.

Includes several brief descriptions of the Drift near Rugby.

1867.—Wood, S. V., jun. On the structure of the Post-glacial Deposits of the South-east of England.—*Quart. Journ. Geol. Soc.*, pp. 394-417.

Some useful notes on the Chalky Boulder-clay.

1867.—Wood, S. V., jun. On a Section at Litcham affording evidence of Land Glaciation during the earlier part of the Glacial Period in England.—*Quart. Journ. Geol. Soc.*, pp. 84-87.

Over much of Norfolk the top 15 or 20 feet of the Chalk is so impure that it is locally called "Marl." "This condition seems to indicate that a churning up of the surface of the chalk has been effected by some action which permitted it again to subside without any considerable intermixture of foreign ingredients; and it is very dissimilar to anything we know to result, or can by geological phenomena gather to have resulted, from water action." At Litcham, not only is the top of the chalk in this state, but the bands of flint have been broken and bent, and the body of the rock contains galls or cavities filled with dark brown clay. This was the result of the passage of a glacier.

1868.—Wood, S. V., jun., and Rome, Rev. J. L. On the Glacial and Post-glacial Structure of Lincolnshire and South-east Yorkshire.—*Quart Journ. Geol. Soc.*, pp. 146-184.

Describes the Holderness Coast-section; traces the beds inland, and correlates them with the Drift of the eastern counties, &c.

1869.—Crosskey, Rev. H. W. The Glacial Epoch in Great Britain. Part I, pp. 70-80.—*Proc. Birm. Nat. Hist. and Micro. Soc.*

The first portion of this paper is devoted to a consideration of the various meanings attached by geologists to such terms as "boulder-clay," &c. The divisions of the Glacial Series as existing in Scotland are then described, and the paper concludes with lists of the marine shells found in glacial deposits in various localities, and the climatal indications afforded by these shells.

1869.—Dawkins, W. B. Distribution of British Post-glacial Mammals.—*Quart. Journ. Geol. Soc.*, pp. 192-215.

Gives detailed lists of the bones found in caves, &c., and river-gravels, including those of the Midland Counties.

1869.—Eyton, Miss C. Notes on the Geology of North Shropshire.

A small book containing some valuable notes.

1869.—Mackintosh, D. Scenery of England and Wales.—Longmans and Co.; pp. 23 and 399; illustrated.

Drift at Shrewsbury described, p. 71. Trescott Boulders, pp. 357-362.

Believes that all the phenomena of the Drift are to be explained by marine submergence.

1869.—Molyneux, W. Burton-on-Trent: its History, its Waters, and its Breweries. — Sm. 8 vo., pp. 268; maps and sections.

Drift sands, gravels, and clay, pp. 173—198. Fossils from Bunter Pebble Beds, p. 160.

All the Needwood Forest area is covered by Drift.

(1) Sands—current-bedded, with coal—passing into sandy gravels, 10 to 50 feet.

(2) Yellow, blue, and red boulder-clays, containing igneous rocks, 2 to 60 feet.

(3) Coarse gravel (on top of all), 6 to 50 feet.

Chalk-flints occur abundantly on Hanbury Wood End.

1870.—Brown, R. On the Physics of Arctic Ice. *Quart. Journ. Geol. Soc.*, pp. 671—701.

Describes (1) the Glacier System of Greenland; (2) Action of Sea-ice; (3) Rise and Fall of the Greenland Coast; (4) Application of the facts regarding Arctic Ice-action as explanatory of Glacial and other Ice-remains in Britain.

1870.— Crosskey, H. W., and Woodward, C. J. Post-Tertiary Beds of the Midland District.—*Proc. Birm. Nat. Hist. and Micro. Soc.*, Part II, pp. 42—55.

This paper contains the first description of the brick-pits at California, near Harborne. At the base a few feet of true boulder-clay (=till) containing striated stones rests on the Bunter Sandstone. This clay is covered by sands, over which comes a considerable thickness (=60 feet) of red clay, containing a few large blocks only; there is more gravel on the top. The largest boulder (3 feet × 2 feet) was a felstone; there were a few granite pebbles in the upper clay. The lower clay is assigned to the action of land-ice; while the thick upper clay "was formed at the bottom of a comparatively deep sea, over which icebergs floated, dropping into it the boulders with which they were charged."

At the Weoley Castle quarry close by there is a "distinctly striated rock surface." The smoothed surface of the rock dips to the South-West, in which direction the principal striae run, although they are crossed in many directions.

Four pits at the Moxley Sandholes are next described.

Fourteen species of marine shells are recorded from the Ketley Gravel Pit near Wellington.

In sands and gravels at Lilleshall, twenty species of marine shells were found.

Other sections at Righton-on-Dunsmore and at Bardon Hill are described.

1870.—Eyton, Miss C. On the Pleistocene Deposits of North Shropshire."—*Geol. Mag.*, pp. 106—113, and p. 545.

A valuable paper, with details of several shell-bearing gravels, including Shrewsbury, Lilleshall, &c.

1870.—De Rance, C. E. On the Glacial Phenomena of Western Lancashire and Cheshire.—*Quart. Journ. Geol. Soc.*, p. 641.

"The Upper Boulder-clay resembles, in the whole of Lancashire from Ulverstone to Manchester, the Lower Boulder-clay of the southern part of the *low country*, in its physical character, chemical composition, included erratic fragments, and the species of shells of mollusca found with it. Both clays contain more Silurian erratics in the N.W., and more carboniferous erratics in the S.E. of Lancashire; both are of a dull Indian-red-coloured tint, caused by the presence of iron derived partly from the Triassic rocks and partly from the hæmatitic deposits of Furness, in which district the Upper Boulder-clay has a deep, almost lurid colour. The colour of the Boulder-clay, as has been observed by Mr. Hull, is perfectly irrespective of the rocks upon which it may lie, being nearly the same when it occurs on the Silurian, Carboniferous, Permian, or Trias." Between these two Boulder-clays come the Middle Drift Sands and Gravels, often 60 feet thick, but sometimes thinning out so as to cause the two clays to coalesce. Marine shells occur in all these divisions.

1870.—Harkness, Prof. R. On the distribution of Wastdale-Crag Blocks, "Shap-fell Granite Boulders," in Westmoreland.—*Quart. Journ. Geol. Soc.*, pp. 517-528; with plate.

Wastdale Crag (near Tebay railway station) is a low rounded hill of porphyritic granite, rising to a height of 1,600 feet, and in area about three square miles. The blocks from it have gone chiefly to the eastward, and many have travelled over the watershed of Stainmoor, which separates Augill Beck from Black Beek (height 1,500 feet) into Balder Dale, &c. Thinks that they were transported by coast ice.

1870.—Lloyd, T. G. B. Superficial Deposits of Portions of the Avon and Severn Valleys.—*Quart. Journ. Geol. Soc.*, pp. 202-225.

Arranges the beds of the Avon Valley under three heads:—(1) *Upper Series*, ranging from 430 feet to 300 feet above sea level; (2) *Lower Series*, 300 feet to 50 feet; (3) *Freshwater Deposits.*

In the *Upper Series* no fewer than seven sub-divisions are made. In that called "B 2" it is easy to recognise typical Chalky Boulder Clay; this clings to the Lias and Rhaetic Formations, while over the Triassic Formation it changes in colour from blue to red. No shells, &c., occur in this Upper Series.

The *Lower Series* may be divided into a "General Flinty Drift" and a "Local Drift." Marine shells and bones of mammals have been found in gravels at Beckford, on the northern base of Bredon Hill.

In the Severn Valley the "Upper Series" ranges from 800 feet to 300 feet above sea-level, and contains marine shells at Willey Park, near Broseley, and at Strethill. The "Lower Series" (300 feet to 50 feet) has yielded marine shells at Frankwell, Shrewsbury; at Leighton, near Buildwas; at Buildwas; at St. James's Pits, Bridgnorth, and at Quat, near Bridgnorth; at Northwick, at Bromwich Hill, at Powick, and at Kempsey—all in or near Worcester; at Fleet's Bank, Sandlin, near Malvern; and at Upton-on-Severn (railway station).

1870.—Lucy, W. C. The Post-Pliocene Drift of Charnwood Forest.—*Geol. Mag.*, vol. VII, pp. 497-499.

Found flints on the summit of Mount Sorrel, and they occur all over the Forest.

1870.—Wilson, J. M. Surface Deposits of Rugby.—*Quart. Journ. Geol. Soc.*, pp. 192-202.

The "deposits on the high levels" (350 to 400 feet above sea-level) may be divided into—(1) The flinty and quartzose drift; (2) Sugary sand with grains of chalk; (3) Clay with pebbles, principally of chalk, distinctly striated.

1870.—Wood, S. V., jun. Sequence of the Glacial Beds.—*Geol. Mag.*, pp. 17-22, 61-68.

Considers that the mollusca are only a safe guide on two points:—"1st, that the presence of *Tellina Balthica* is a test that the bed yielding it belongs to *Glacial or Post-glacial* formations, and not to any of the Crag series; and 2nd, that the absence of *Tellina obliqua* affords a presumption that the bed—at least any English bed—from which it is absent, is of *Post-glacial* age."

1870.—Wood, S. V., jun. On the Relation of the Boulder Clay without chalk of the North of England, to the Great Chalky Boulder Clay of the South.—*Quart. Journ. Geol. Soc.*, pp. 90-111; with plate.

The "Cromer Contorted Drift" is overlaid by "Middle Glacial Sands and Gravels," which are seen at many points in the Eastern and East-Midland Counties. They have yielded 63 species of marine shells, "all but one of them collected within a radius of a few miles around Yarmouth." Next comes the "Great Chalky Boulder Clay," which is succeeded (passing upwards) by "the Purple Clay, with Chalk, diminishing in quantity upwards"; while newer still is the "Purple Clay, without Chalk, but with Shap Boulders."

1870.—Woodward, C. J. On a Method of Mapping the Boulders of the Midland District.—*Proc. Birm. Nat. Hist. and Micro. Soc.*, part II, pp. 55-57.

Suggests that the erratic blocks of the district should be systematically studied; specimens collected from them; and their positions marked on the Ordnance Maps.

1870.—Woodward, C. J. Report of the progress made in Mapping the Boulders.—*Proc. Birm. Nat. Hist. and Micro. Soc.*, part II, pp. 57-58.

Rough six-inch maps have been prepared (43 in number, so far) each representing one square mile of country; and work has been done on five or six of these. The greatest number of boulders was met with in the neighbourhood of Tettenhall. Granite is abundant to the north of Wolverhampton, but is met with very sparingly in the neighbourhood of Birmingham. Only one scratched boulder is recorded.

1870.—Woodward, C. J. On some "'Swilleys' of the Lias."—*Proc. Birm. Nat. Hist. and Micro. Soc.*, pp. 63-64; with one plate.

The term "swilley" is used in South Warwickshire for almost any disturbance of the strata. In two Lower Lias quarries near Grafton, and in one near Binton, the layers of the limestone nearest the surface are seen to be bent upwards into a kind of broken arch. A quarry owner at Grafton states that these disturbances "vary much in their extent, sometimes running in a ridge for a hundred yards or so, while in other cases the beds are only lifted in one place.

The author offers two hypotheses:—(*a*) Water may have penetrated between the beds of limestone, and then under pressure has lifted up the upper beds; (*b*) Horizontal pressure has been applied by an iceberg, or by a sliding mountain mass, and this has ridged up the beds.

1871.—De Rance, C. E. Glaciation of the North-west of England. *Geol. Mag.*, pp. 412-418.

On p. 415 states—"in 1861 I found in the sands of Leamington, in Warwickshire, Corals from the Lias of Cheltenham, Pectens and other fossils from the Red Crag, and a Nautilus from the London Clay. And in the neighbourhood of Crewe Mr. Taylor, F.G.S., has recorded the presence of a great number of chalk flints."

1872.—Dakyns, J. R. On the Glacial Phenomena of the Yorkshire Uplands.—*Quart. Journ. Geol. Soc.*, pp. 382-388.

In Derbyshire, and in Yorkshire south of the Aire basin, no glacial drift has been found on the eastern side of the Pennine Chain, save where it is broken through by the valleys of the Wye, Calder, and Aire.

1872.—Mackintosh, D. On a Sea-coast Section of Boulder-clay in Cheshire.—*Quart. Journ. Geol. Soc.*, pp. 388-392.

The section described is at Dawpool, on the N.E. side of the estuary of the Dee. It reaches a height of 50 feet, and extends for three miles. Here the "Middle Glacial Sands" are absent, but the Lower and Upper Boulder-clays can be distinctly separated. The Lower Boulder-clay here contains marine shells (this is exceptional), of which fifteen species have been identified. Scotch and Lake-district boulders occur in abundance.

1872.—Symonds, Rev. W. S. Records of the Rocks, p. 433; illustrated.—J. Murray, London.

Bridgnorth drift described, p. 403; and that at Bushbury, p. 410.

1872.—Tiddeman, R. H. On the evidence for the Ice-sheet in North Lancashire and adjacent parts of Yorkshire and Westmoreland.—*Quart. Journ. Geol. Soc.*, pp. 471-490; with coloured plate.

In this district "there are proofs of a widespread and almost universal glaciation—that whereas the drainage of this district is to the S.W., the general movement of the ice over it was to the S. or S.S.E. across deep valleys, and over hills of considerable elevation—that this is proved by the scratches on the rocks, the direction and method of transport of the Till, its materials, and their arrangement along lines coinciding with the scratches, as well as by the superficial disturbances of the rocks. I showed that these facts would admit of readier explanation by means of an ice-sheet than by any other glacial agent. But the direction of the movement requires a further explanation. Under ordinary circumstances an ice-sheet would be working down from the watershed to the sea in the direction of the main valleys; but this was not so. There must have been a great barrier along what is now the seaside plain to dam up the mouths of these valleys to a great height and prevent their discharge of ice to the south-west. Just where this barrier should have existed we find evidence of a great stream of ice coming from the Lake-district, and bearing with it rock specimens of that country. This must have been of considerable height and very persistent in its flow to divert the ice-drainage of the basins of the Lune and the Ribble from their natural course; but that it did so is very evident. This barrier was but the line of junction of the ice of the Pennine Chain with that from the Lake-district, and to the eye they must have presented only the appearance of one great sea of ice; and this barrier must have been supported or shouldered up by other ice coming from portions of the Lake-district still further west."

All the evidence shows that a great ice-sheet passed over this district, moving towards the S. and S.S.E.

1873.—British Association: Erratic Blocks Committee.

At the meeting of the Association in Brighton, in 1872, a Committee was appointed "For the purpose of ascertaining the existence in different parts of the United Kingdom of any Erratic Blocks or Boulders, of indicating on maps their position and height above the sea, as also of ascertaining the nature of the rocks composing these blocks, their size, shape, and other particulars of interest, and of endeavouring to prevent the destruction of such blocks as in the opinion of the Committee are worthy of being preserved."

The first members of the Committee were Profs. Ramsay, Geikie, J. Young, Nicol, Hull, Harkness, Sir R. Griffith, Bart., Drs. Bryce, King, A. Mitchell, Rev. H. W. Crosskey, and Messrs. Prestwich, Hughes, W. Jolly, D. Milne-Home, and Pengelly.

The first Report—drawn up by the Rev. H. W. Crosskey as Secretary—was submitted to the meeting at Bradford in 1873, and is printed (pp. 188-194) in the volume containing the record of that meeting [John Murray, Albemarle Street, London, 1874].

This first report states that, as the Royal Society of Edinburgh has appointed a Committee for the examination of the Scottish Boulders, it will not be necessary to include Scotland in the area to be considered.*

* In the following notes, the descriptions of Midland boulders are extracted with some detail; those from other districts are referred to briefly or not at all.—W. J. H.

1.—*The Hugglescote Cutting* (two miles from Bardon Hill) has yielded great numbers of Charnwood Forest Boulders ("porphyritic greenstone"), four of which have been removed to the grounds of the Leicester Town Museum.

2.—*Ketley Gravel-pit* (near Wellington), 357 feet above sea-level; thirteen species of marine shells; Charnwood rocks are said to occur here, but this error was subsequently corrected.

3.—*Birmingham Natural History Society* report:—

(*a*) Great accumulation of boulders at Tettenhall, Bushbury, and Cannock. Large numbers also at Penkridge, Shareshill, Brewood, Codsall, Stone, Shifnal, Harborne, and Bridgnorth.

(*b*) Southernmost point for boulders observed is Bromsgrove; most easterly, Rugeley. A very large boulder of grey granite (6 ft. by 5 ft. exposed) occurs in a field near Red-hill Farm, between Stafford and Stone. Granite boulders are abundant at Tettenhall and Wolverhampton; but felstones occur instead at Harborne and Birmingham.

1873.—Geikie, Jas. On the Glacial Phenomena of the Long Island or Outer Hebrides: First Paper.—*Quart. Journ. Geol. Soc.*, pp. 532-545.

"Lewis has been traversed from S.E. to N.W. across its whole breadth by glacier-ice." This ice came from the mainland and must have attained a prodigious thickness (3,000 feet or more). "The great ice-sheet did not

stay its onward march until it reached the edge of the 100-fathom plateau, some 45 or 50 miles beyond the Outer Hebrides, and calved its icebergs in the deep waters of the Atlantic."

1873.—Mackintosh, D. Boulders of the North-west of England and the Welsh Borders.— *Quart. Journ. Geol. Soc.*, pp. 351-359.

A variety of Dalbeattie granite contains large oblong brown crystals of felspar, and is liable to be mistaken for Shap granite. The Trescott and Trysull boulders near Wolverhampton are described on p. 358.

In the discussion, Mr. Koch "mentioned that in the late floods in Bohemia blocks as large as 6 feet by 4 feet had been transported by the rivers."

1873.—Ward, J. C. The Glaciation of the Northern Part of the Lake District.—*Quart. Journ. Geol. Soc.*, pp. 422-441; with plate.

The striae, and the distribution of the boulders, point to land-ice moving from south to north.

In the discussion Professor Ramsay said—"As to the question of general glaciation he thought it probable that much of the northern part of Europe had at one time been coated with ice, and to such an extent that it occupied the greater part of the bed of the shallow seas. But even if there were this great ice-sheet, and the general direction of its flow was from north to south, yet there might, in the body of the ice, be upper and under currents, going to a certain extent in opposite directions, and mainly guided by the surface configuration of the ground beneath. He thought that some trace of this might be found in existing hilly regions; and that, especially in deep valleys, the upper portion of the ice must, of necessity, have had a tendency to pass over that which occupied the bottom of the valley."

1874.—Belt, Thos. The Steppes of Siberia.—*Quart. Journ. Geol. Soc.*, pp. 490-498.

Thinks that ice from the north dammed up the great northward-flowing rivers. Their waters then formed lakes in which the vast level sheets of sand and loam, which cover the Northern Plains of Asia, were deposited.

Similarly, "if the ice (during the Glacial Period) once filled the beds of the German Ocean and the Irish Sea, all our rivers running to the west and to the east must have at one time been dammed back by it. Every lateral valley in the North of England and in Scotland was at one time or another occupied by a glacial lake."

1874.—British Association: Erratic Blocks Committee. J. Murray, Albemarle Street, London.

Belfast Meeting.—"In the Midlands the softness of the Bunter Sandstones has prevented the preservation of glacial striae to any extent; but in one part (California, near Harborne) they have been observed upon the native rock."

1874.—Mackintosh, D. On the Traces of a Great Ice-sheet in the Southern Part of the Lake District, and in North Wales.—*Quart. Journ. Geol. Soc.*, pp. 174-180; with plate.

In the southern part of the Lake District the general ice-flow must have been from north to south, and it was largely independent of the present drainage of the country.

1874.—Rendu, M. le Chanoine. Theory of the Glaciers of Savoy (translated by A. Wills; with notes by P. G. Tait and John Ruskin; edited by Geo. Forbes).—8vo., pp. 216. Macmillan and Co., London.

The original memoir was published (in France) in 1840. Its value lies largely in the fact that Rendu was one of the very first men to study glaciers scientifically.

1874.—Reade, T. M. The Drift-beds of the North-west of England.—Part I, Shells of the Lancashire and Cheshire Low-level Boulder-clay and Sands.—*Quart. Journ. Geol. Soc.*, pp. 27-37.

Comparative lists with other localities for the "shell-fragments" are given. The localities are chiefly in the neighbourhood of Liverpool. "The whole of the 44 species of shells were distributed through the drift. In nearly every case they were taken from the *clay* beds; for though in the included sand-seams shells are occasionally met with, they are, as a rule, rare." The shells are "small, fragmentary, and rolled, sparsely distributed through the clay, and not in any case found in zones or beds."

1874.—Shone, W. Discovery of Foraminifera, &c., in the Boulder-clays of Cheshire.—*Quart. Journ. Geol. Soc.*, pp. 181-185.

The forams were obtained by washing out the contents of gasteropod shells, &c., contained in the drift-clays. "The fact that the *Turritellae* filled with the greyish-white sand yielded abundantly Foraminifera and Ostracoda, and that those wholly filled with the red clay in which they were imbedded contained scarcely any, would appear to suggest that the former had been transported to their present positions by the same agency which brought the pebbly gravel and striated erratics which lie mingled with them in the clay."

Mr. Shone also describes this work in a very interesting article in the *Midland Naturalist*, p. 292, for 1878.

1875.—British Association Report: Erratic Blocks Committee.

Bristol Meeting.—In the *Bromsgrove* district 93 felspathic boulders have been examined; three varieties have been noticed. (1) compact, (2) containing small porphyritic crystals, (3) a decided ash. The colour is a dark grey to light grey, sometimes with a greenish tinge, but generally bluish. No granites have been seen in this district.

Group of felspathic boulders between *Northfield* and King's Norton (just above the letter *d* of word "Northfield" on Ordnance Map). Similar group at *King's Norton.*

"A boulder of compact felstone has been found in Cannon Hill Park, Birmingham, $72 \times 51 \times 48$ inches, rounded in parts and subangular, and to some extent smoothed and polished. It was dug out of valley-drift in making a lake." [This boulder is preserved within the park.]

1875.—Goodchild, J. G. Glacial Phenomena of the Eden Valley and the Western Parts of the Yorkshire Dale District.—*Quart. Journ. Geol. Soc.*, pp. 55-99; with coloured plate.

This admirable paper should be read in conjunction with that by Mr. Tiddeman on "The Evidence for the Ice-Sheet in North Lancashire, &c." *

Indeed this paper of Mr. Goodchild's helped to lay the foundation for what has been called "The New School of Glacial Geology," by which the Glacial Period is considered to have been one continuous period of cold, while—as far as England is concerned—there was neither elevation nor submergence to any noteworthy extent.

Mr. Goodchild's conclusions are:—

(1) The whole of the district treated of in the paper was once enveloped in a part of the great ice-sheet whose existence in adjoining districts has been demonstrated by Messrs. Tiddeman and Ward.

(2) There seems evidence to prove that the upper limit of this part of the ice-sheet stood somewhere between 2,200 and 2,400 feet above the present sea-level, at the points where the ice-sheet attained its greatest thickness.

(3) A line of ice-sheet extended nearly along the present watershed of the Lake district to the highest ground in the Yorkshire dales. To the south of this line the ice at high levels flowed straight away over the fells into Lancashire and West Yorkshire; while that to the north, after flowing a short distance into the Eden valley, was turned to the east, and compelled to flow over Stainmoor towards the North Sea.

(4) Some evidence has been given to prove that few even of the smaller valleys could have been the work of ice, but that, on the contrary, the ice seems to have tended rather to level the minor inequalities of the surface, and thus to efface the smaller valleys.

(5) It has also been shown that much of the surface-configuration that is characteristic of the Dale district has been due to glacial erosion—and

* *Q. J. G. S.* for 1872, p. 471.

that, as a perfect gradation in form may be traced from the straight lines of scar, which it seems impossible to refer to any other than glacial origin, to the crescentic scars that have all the characteristics of cirques, these also have originated through glacial erosion.

(6) In treating of the origin of Drift, the principal conclusions are, that the facts observed are irreconcilable with either the *moraine-profonde* or the marine theory—and that the angular moraine-like drift occasionally found in parts of the dales, the upper and lower tills and the intercalated beds, the deposits of sand and gravel that form the eskers, and, finally, the numerous boulders that are left at nearly all elevations, are each and all the results of the melting of a great sheet of land-ice that was charged throughout with rock-fragments of all sizes and of all the kinds occurring within the area wherein the ice originated.

(7) Lastly, the present unmodified form of the drumlins and eskers, the entire absence of anything like a terrace of marine origin, and the difficulty of pointing to any case of boulder-dispersal in directions that glacial currents may not have taken—all seem to prove that, whatever submergence followed the climax of the glacial period, most of the existing glacial phenomena are the work only of the ice-sheet. So little, indeed, has the aspect of the country changed in Post-glacial times that in many places the larger rivers are even now above the bases of the adjoining drift-mounds, whose present form can hardly be referred to any other than glacial action; and Post-glacial denudation generally has effected so little that by far the greater part of the present surface-configuration has, in one way or another, resulted from the former presence of the great ice-sheet.

1875.—Judd, J. W. Geology of Rutland, &c. (Geological Survey Memoir). Large 8vo., pp. XV and 320; plates and woodcuts; price 12/6. The Post-tertiary Deposits are described pp. 240-253.

Some gravels, sands, and brick-earths are considered to be *pre-glacial*, they contain *local* rocks only. The chief glacial deposit of the district is the Great Chalky Boulder-clay, which has gravels and sands both above and below, and even inter-stratified with it. "Although some geologists have attempted to show that the great glacial formations, composed of clay, and sand or gravel, respectively, belong to perfectly distinct periods, and mark different climatal and physical conditions in the Midland district of England, and even entire changes in the disposition of the land and sea of the period; yet nothing can be clearer that in the area we are more particularly describing the beds of glacial clay, sand and gravel, replace one another in the most capricious manner, and are evidently dependent on the action of causes of extremely local character." The total thickness of these glacial beds in this district is "in places probably not less than 300 feet." Post-glacial deposits also occur, including fluviatile and marine (Fenland) gravels, peat, &c.

1875.—Croll, Jas. Climate and Time in their Geological Relations. —Daldy, Isbister, and Co.

The author's main object in writing this book was to show that the changes in the eccentricity of the earth's orbit which we know to have taken place in the past, must have *indirectly* produced changes in the earth's climate sufficiently important to account for the phenomena of glacial periods.

As a sequel to this book, Dr. Croll published a similar work entitled "Climate and Cosmology" in 1885, in which he replied to his numerous critics with much ability.

1875.—Ward, J. Clifton. The Glaciation of the Southern part of the Lake district and the Glacial Origin of the Lake Basins of Cumberland and Westmoreland.—*Quart. Journ. Geol. Soc.*, pp. 152-166 ; with plate.

Summary.—1. During the period of maximum glaciation, the various glaciers of this southern part of the Lake district, as of the northern, were more or less confluent, and most of the lower elevations were buried under a continuous sheet of ice, which often moved diagonally across the lower parts of ridges separating valley from valley.

2. The occurrence of some glacial scratches crossing water-shedding lines at high elevations, in a general east and west direction, and frequently in passes or cols, seems to point, perhaps somewhat doubtfully, to the agency of floating ice, and to support the supposition that the submergence reached to more than 2,000 feet, and may have extended to but little short of 2,500 feet.

3. The existing moraines are the product of the second land glaciation ; the glaciers of this period seem never to have become confluent, as in the former, but occupied the heads of all the principal valleys.

4. Several of the larger lakes, such as Wastwater and Windermere, are rock-basins running down beneath the present sea-level.

5. These rock-basins, however, are but shallow grooves at the bottom of the valleys in which they occur ; and their depth is small as compared with the thickness of the ice which moved over these spots. Hence it seems most probable that the theory of glacial erosion (of lakes) is the true one, and the points of evidence brought forward in the case of Wastwater are strongly confirmatory.

6. Mountain tarns appear to be due, sometimes wholly to glacial erosion, sometimes to this combined with a moraine dam, and occasionally to the pounding back of water by moraines alone, or moraine-like mounds, at the foot of snow-slopes.

1876.—Aitken, Jno. Observations on the Unequal Distribution of Drift on opposite sides of the Pennine Chain, in the country about the source of the River Calder.

"A marked difference exists in the distribution of drift on opposite sides of the Pennine Chain, a difference amounting in some instances to an entire absence of that material on the easterly slopes for many miles from the water-shed of the country, and over a considerable portion of its length, notwithstanding that those deposits overspread the great plains of Lancashire and Cheshire in great force, and are found mounting up upon the flanks of those hills on their western sides to very considerable elevations, approaching closely, in some cases, to the culminating ridge, and in others, where the chain is crossed by intersecting valleys, to some hundreds of feet in excess of the summit level of these gorges."

Thinks that the cross valleys were filled (during the Glacial epoch) with "ice or snow so consolidated and fixed in the sinuous channels as to remain stationary and inert while the great mass of glacial ice, in two sheets, separated by the more elevated portions of the great anticlinal range, traversed its eastern and western sides on its march from north to south."

1876.—British Association Report: Erratic Blocks Committee.

Glasgow Meeting.—Near *Harborne*, 160 rounded and subangular blocks have been examined: 90 of these are felstones, 55 are of local rocks (Carboniferous, Permian, Trias). At Flavell's Farm, California, is a grey granite boulder 24 × 20 × 12 inches. Near Hole Farm, Moor Street, about two miles east of Halesowen, a boulder $3\frac{1}{2} \times 2\frac{1}{2} \times 2$ feet, consists of a compact almost hornstone-like matrix, containing distinct included fragments and porphyritic felspar crystals.

North Wales.—Mr. Mackintosh describes the dispersal of Arenig rocks as far as the Welsh Border.

1876.—Davies, D. C. On the Drift of the North Wales Border. —*Proc. Geol. Assoc.*, pp. 423-439; with plate.

Describes the Drift round Oswestry, &c. The materials of the Drift "are the same from bottom to top," local and northern rocks being intermingled.

1876.—Heming, W. T. Notes of Field Meeting on Lickey Hills in 1866.—*Proc. Dudley Geol. Soc.*, pp. 19-20.

"Attention was directed to the large number of erratic blocks, and the quantity of Drift near the Lickey. The number of large blocks on each side of the ridge is enormous, some of them weighing a ton, and others much smaller. They lie all about the town of Bromsgrove, and the villages of Burcot and Northfield, and as far south as Feckenham. The Drift lies in numerous and interesting patches, and some of it contains a large proportion of broken-up shale, as sharp at the edges as though chipped but yesterday from its parent rock, while further off and at less elevation, the Drift contains the same materials, but worn and rounded at the edges."

1876.—Penning, W. H. Physical Geology of East Anglia during the Glacial Period.—*Quart. Journ. Geol. Soc.*, pp. 191-204; with plate.

The "Middle Glacial Sands and Gravels" were deposited in a sea traversed by rapid currents. Submergence continued, and the Chalky Boulder Clay was dropped from icebergs upon the Sands, &c. The "Post-glacial" deposits were formed from the wash of the boulder-clay during its emergence when elevation took place.

1876.—Ramsay, Sir A. C. How Anglesey became an Island.—*Quart. Journ. Geol. Soc.*, pp. 116-122; with plate.

"The Welsh group of mountains, as a whole, was not over-ridden by a great universal ice-sheet proceeding from the far north. In the main, every valley was filled by its own special glacier. In such a case, however, there were many deviations consequent on under and upper ice-currents, the upper parts of glaciers diverging from the direction of the underflow, and passing across what are now low watersheds."

The glaciers of the Snowdonian range never quite reached the (present) Menai Straits. The glacial striae of Anglesey "point directly to the mountains of Cumberland, a country which, lying further north, was at one time buried so deeply under snow and ice, that almost all its mountains look simply like gigantic *roches moutonnées*; for Cumberland was far more intensely glaciated than the more southern region of Wales. From Cumberland a vast mass of ice flowed southward; and, reinforced by the ice-streams that came from the mountains of Carrick, in the south of Scotland, and perhaps even from the basin of the Clyde, it overspread the region now occupied by the shallow sea of Morecambe, Lancaster, and Liverpool bays, that lie between Cumberland and Anglesey (nowhere more than 30 fathoms deep), and pressing still further to the south-west, covered the whole of the low ground of Anglesey, and went to some unknown distance beyond. Furthermore, in my opinion, so great was the size and power of this ice-flow, that it hindered the glaciers of Llanberis and Nant-ffrancon from encroaching on the territory of Anglesey, and these simply joined the larger on-flowing glacier as minor tributary ice-streams."

The great glacier ploughed out a great groove in the soft carboniferous strata, and this groove now constitutes the Menai Straits.

1877.—Belt, Thos. On the Steppes of Southern Russia.—*Quart. Journ. Geol. Soc.*, pp. 843-862.

Gives in abstract (from the "Geology of Russia in Europe") Murchison's description of the Northern Drift as "extending all the way from the German Ocean on the west, to the White Sea on the east, a vast zone of country nearly 2,000 miles in length, and from 400 to 800 miles in width, with colossal blocks of crystalline rocks, the whole of which have been brought from Scandinavia, Finland, and Lapland. This detritus has been borne

southwards in long zones, often separated from each other by depressions, occasionally of great width, in which few or no blocks are discernible. Hills or slopes, 200 or 300 feet high, are covered with blocks, whilst the intervening valleys are free from them. The Valdai Hills, which rise to over 1,100 feet above the sea, are strewn with blocks of granite, gneiss, greenstone, and porphyry, which have come from Finland." Mr. Belt regards this as the moraine of a great ice-sheet which pounded back the rivers so that a great freshwater lake was formed in which the loess or diluvial clays of the Steppes was deposited.

1877.—British Association Report: Erratic Blocks Committee.

Plymouth Meeting.—Rev. J. Caswell gives list of boulders near *Oscott College* (N. Birmingham); 21 are felstones (largest 56 × 24 × 18) at Osborne's Barn, Old Hall, Thornhill, Barr Hall, King's Vale, Castle Bromwich, Paper Mill End, Old Chester Road, Wilton Hall and Stockland Green. Granites, one in a wall at Queeslet (12 × 6 × ? inches), and one by roadside at Old Bell and Cuckoo (1 cub. ft.) No boulders at Perry, Sutton Park, Tyburn, &c.

1877.—Burgess, J. T. Flint, Stone, and Bronze Implements in Warwickshire.—*Proc. Warwickshire Field Club*, p. 23.

1877.—Clarke, J. E. Ancient Boulder Gravels (near Walsall).—*Nat. Hist. Journ.*, vol. I, p. 120.

1877.—Harrison, W. J. The Geology of Leicester and Rutland. Large 8vo, 67 pp., with twelve photographs.

The photograph of Sopewell Syenite Quarry, near Sapcote, shows a rock-surface which appears to have been smoothed and glaciated by ice. A photograph of a part of the granite rocks at Mount Sorrel, from which the surface soil has been removed, shows rocks not only smoothed and rounded by ice, but also striated. Part of the lateral moraine of the Great Chalky Boulder Clay Glacier rests on the rocks here. A typical section of the work done by this great glacier a few miles further south down the Soar Valley is thus described on p. 45: "Boulder Clay was exposed in widening the cutting of the Midland Main Line between Leicester and Wigston. Its thickness here was between 20 and 30 feet. At the base the Lower Lias shales and limestones were exposed to a depth of 3 or 4 feet for a distance of about 400 yards. The limestones were most beautifully striated *in situ*, the slightness of their dip having prevented the ripping-up of the beds to any great extent, and the thick covering of clay having preserved them from the percolation of water. Oblong slabs of limestone, torn off, were to be seen lying in close proximity to the outcrop of each stratum and a little to the south of it. In one spot the strata were bent up for a few yards into a sharp antielinal curve. The drift itself was a compact slatey-blue clay, in which numerous lumps of coal stood out in striking comparison with white, partly decomposed masses of sandstone."

1877.—Mackintosh, D. On a number of New Sections around the Estuary of the Dee, which exhibit Phenomena having an important bearing on the Origin of Boulder-clay and the sequence of Glacial Events.—*Quart. Journ. Geol. Soc.*, pp. 730-739.

There is a distinct and undulating line of junction between the Upper and the Lower Boulder-clays wherever the Middle Sands are absent. And between these sands and the Upper Boulder-clay "there is almost universally a clean and straight or undulating line of junction, without the slightest commingling of materials." The author thinks that this proves "that the (upper) clay could not have been brought by land-ice, *because land-ice could not have pushed its* moraine profonde *for scores of miles over an extensive deposit of yielding sand and gravel without confusedly mixing up the two formations.*"

1877.—Rance, C. E. de. Superficial Geology of the Country adjoining the Coasts of S. W. Lancashire (Geological Survey Memoir), pp. 139, with 20 woodcuts. Price 10/6.—Eyre and Spottiswoode, London.

A capital monograph of the drift deposits in a portion of the country where they are not only widely spread, but where they have been long and carefully studied.

1877.—Wood, S. V., and Harmer, F. W. The Later Tertiary Geology of East Anglia.—*Quart. Journ. Geol. Soc.*, p. 74.

The authors discuss—(1) the unfossiliferous sands overlying the Red Crag; (2) the unconformity between the Lower and Middle Glacial beds, and the interglacial valley excavation; (3) the mode in which the Middle Glacial series was accumulated, and the way in which the sequence of the beds posterior to the lower glacial series is to be traced.

1878.—British Association Report: Erratic Blocks Committee.

Dublin Meeting (Sixth Report).—The Bromsgrove boulders are described as "an *overshot load* from the great Arenig stream of erratics which has found its way through Llangollen Vale into the central plain of England, and which has left large blocks about Chirk and Welsh Frankton (west of Ellesmere)."

1878.—Crosskey, Rev. H. W. On the Microscopical Examination of Clay.—*Midland Naturalist*, pp. 328-9.

1. The clay must be *thoroughly dried.* Fill a pie-dish with the clay and allow it to dry *gradually*—say on the chimney-piece of a warm room.

2. Place the dried clay in a bowl of water and allow it to stand for a few hours, when it will be found to disintegrate when stirred gently.

3. Allow to stand for an hour. The whitish scum which will (if the clay be at all rich in organisms) rise to the top is the most valuable of all. Skim it off, and pour it into a tin cylinder, the lower end of which has been covered with a piece of fine muslin held on to the cylinder by means of a rubber band. The water drains away through the muslin, and leaves any organisms behind.

This drying and soaking of the clay should be repeated until it fails to yield any more scum or "floatings."

4. Next *wash* the clay thoroughly and repeatedly by adding water to it, stirring and pouring off the muddy liquid.

5. Lastly, examine the residue (which will be chiefly sand) for such organisms as would not float.

1878.—Crosskey, Rev. H. W. Fossiliferous Clay at Wolverhampton, *Mid. Nat.*, p. 298.

The ounce or two of clay examined was "found in excavating a drain." It contained two species of forams, two echinoderm spines, and fragments of *Tellina balthica.*

1878.—Dawson, G. M. On the Superficial Geology of British Columbia.—*Quart. Journ. Geol. Soc.*, pp. 89-123; with map.

Some useful observations on glacial drift, striation, &c. Marine shells occur in sandy clays and sands; "these, or at least their lower beds, were probably formed at the foot of the glacier when retreating, the sea standing considerably higher than at present."

1878.—Fielden, H. W., and De Rance, C. E. Geology of the Coasts of the Arctic Lands, visited by the late British Expedition, under Capt. Sir George Nares. — *Quart. Journ. Geol. Soc.*, pp. 556-567.

Glacial phenomena are described pp. 563-567.

1878.—Geikie, Jas. On the Glacial Phenomena of the Long Island or Outer Hebrides; second paper.—*Quart. Journ. Geol. Soc.*, pp. 819-870; with plate.

A paper full of valuable information.

Ice from the Scotch mainland crossed the Minch, and its *upper* layers went westward right over the top of the Island; but the *lower* layers of thin ice were deflected to north and to south, and eroded a deep channel in the sea-floor of the Minch close to the chain of islands.

1878.—Harrison, W. J. Digging out a Boulder.—*Mid. Nat.*, p. 153.

The boulder has long been known as the "Holstone." It is a mass of Mount Sorrel granite, weighing about 15 tons, and lies in a field $2\frac{3}{4}$ miles north-east of Leicester. It is thus about six miles south-east of its native mass, and has crossed the Soar Valley from west to east. Its present height above sea level is about 260 feet.

1878.—Harrison, W. J. Scheme for the Examination of the Glacial Deposits of the Midland Counties of England.—*Mid. Nat.*, pp. 181, 242, 312.

At the first Annual Meeting of the Midland Union of Natural History Societies (held in Birmingham, May 27th and 28th, 1878) Mr. W. J. Harrison moved, Mr. Lawson Tait seconded, and it was carried—"That the subject of the glacial drift deposits be referred to the Council as one well adapted for conjoint observation by the Societies in the Union."

The following notes were subsequently drawn up by Mr. Harrison, and were circulated widely in the Midlands :—

"I. The Workers.—No Society can plead an absence of material on which to work. The stratified rocks which constitute what we term the 'solid geology' of our country run in tolerably definite bands (from N.E. to SW.), but the glacial drift is scattered irregularly all over the face of the country, and is with us everywhere. Each Society should appoint one of its members who should act as secretary or record keeper for the particular study we propose to attempt. The other members who are willing to aid actively in the task should give in their names to him, and he should summon meetings of such members at frequent intervals.

"A chief duty of the record secretary would be to keep a large 'observations book,' in which to enter all notes and discoveries. If this book contained plenty of 'guards' such members as preferred it might write out the results of their own work, which could then be pasted in the book.

"As it would be absolutely necessary to gain personal experience, it would probably be easy to arrange for joint meetings of all who take an active interest in this work in the various districts in turn. The typical deposits of the east and west coasts and of Scotland would also be visited and examined.

"II. The Work.—In the first place it would be necessary for each worker, or at all events each Society, to obtain the Ordnance Maps, both plain and geologically coloured, of their neighbourhood.

"Upon the plain maps they should distinguish by dots and numbers the precise position of every gravel-pit, brick-pit, &c., where the surface deposits are well exposed. Each of these sections should then be visited in turn and carefully examined. Each should be measured, and a plan and section—no matter how rough, if fairly accurate—drawn to scale; if a water-colour sketch could be made of the principal 'face' so much the better. In as many cases as possible an idea of the height of each point above the sea level should be

obtained, either by aneroid, levelling, or computation. The dip, if any, of the layers must be noted, false bedding looked out for, and especially in the clayey deposits any indications of *bedding* remarked. Specimens from each point must be collected. If in wooden boxes about 6 in. by 4 in. an average specimen of each deposit could be secured, it would be of service in comparing with other localities.. The stones must be carefully examined for striations, and so also the rock surfaces below, when exposed. If 100 stones are collected at random from any pit, they should then be sorted according to their composition, and the proportions stated. Specimens of every variety must of course be secured for reference. Fossils must be carefully looked for. So far as I know, not one shell has yet turned up in the drift deposits of the Midlands proper. Entire and large shells must not be hoped for, the smallest fragments will be acceptable, and the sand must be washed and examined microscopically for foraminifera, &c.

"The large boulders will almost force themselves upon our attention. Good specimens of each, measuring not less than 4 in. by 3 in., must be obtained, and every possible fact recorded about them. Much information may often be got from rustics and dwellers in the neighbourhood generally, and the ideas so elicited are often of the most racy description !

"When an examination of the principal open sections has been completed in this way, we shall be beginning to obtain some familiarity with our task, and must endeavour to connect our observations so as to make complete maps of the surface deposits; to connect, that is to say, the various exposures, so as to show what deposits are present under grass-covered fields or wheat crops, as well as in the gravel-pits and brick-pits which we can so easily examine. This is a point, however, which we can consider further on, only remembering in the meantime to make as many notes about water supply and well sections as we can.

"It will be necessary to endeavour to identify the rocks of which the boulders are composed, so as to determine the direction in which the ice-sheet has travelled. For this purpose typical collections of Welsh rocks, of those of the Lake District, and of Charnwood Forest, will be most useful. I shall be glad to forward to any one who is in want of them for this purpose, a small collection of typical Charnwood specimens, and doubtless dwellers near other regions of hard and old rocks would also help in this way.

"In a separate note-book *enter at the time* as many particulars as possible; omit nothing however insignificant, and let each point be visited more than once, and by different workers if possible. It will be found useful to have a small number book, containing sheets of numbers, say from 1 to 1,000, gummed and perforated. When a specimen of a boulder, &c., is obtained, let a number be at once gummed on it, whilst in the note-book the same number is written down with full description of locality. I have found this the best of many plans.

"The apparatus required in addition to a map is not much. A geological hammer with a square head, and belt with flap to carry the hammer in; a small compass, a little acid bottle to test for carbonate of lime, a good satchel or stout gamekeeper's bag, a clinometer, a pocket lens: all of these are useful,

but I have known a working man with a coal-pick do excellent work. It is a great thing to walk much ; to get a thorough geographical idea of the tract of country you are about to examine. Suppose that at the meeting of your 'Committee on the Drift Deposits' you with a friend have undertaken the examination of a district including, say, ten square miles, then the best thing to do is to learn this little region thoroughly, to master the course of every brook and streamlet, the position of every house and hedgerow. The number of new facts that are sure to turn up will surprise you."

A list of reference books on the subject is then given.

"No very special training is needed on the part of those who are willing to lend a helping hand. For instance, we want to know how far the chalky boulder-clay of the Eastern Counties extends to the west and south ; and also the relations to it of certain beds of flinty gravel and sand. Now everybody knows the appearance of a lump of chalk and a piece of flint, and we ought to be able to fix the westward extension of these beds to a certainty. I have never seen the clay full of bits of chalk in size from a pin's head upwards, at any point west of Charnwood Forest, but then I have not enjoyed many opportunities of examining the drift of Staffordshire, Warwickshire, &c. The flinty gravel appears to extend further west, but what is its limit in this direction ?"

1878.—Lucy, W. C. On the Extension of the Northern Drift and Boulder Clay over the Cotswold Range.— *Proc. Cotswold Club*, vol. VII, pp. 50-61.

1878.—Percival, S. G. *Orthis redux* in Midland Bunter Pebbles. *Geol. Mag.*, Decade II, Vol. V, p. 333.

"The Drift of the Midland Counties is mainly composed of the re-distributed Bunter Conglomerate." The author presented the Birmingham Naturalist's Society with collections of pebbles from the Drift and from the Bunter in 1872 ; and sent another set to the Jermyn Street Museum.

1878.—Shone, W. On the Glacial Deposits of West Cheshire, together with lists of the Fauna found in the Drift of Cheshire and adjoining Counties.—*Quart. Journ. Geol. Soc.*, pp. 383-397.

The "Upper Boulder-clay" is of a reddish-brown colour, much jointed, and with blue partings ; it contains marine shells. The "Middle Sands" also contain shells. The "Lower Boulder-clay" is a very mixed deposit, with numerous striated erraties. Valuable and detailed lists of the species of shells found are given ; and these are compared with the species found in other localities. The mixture of southern and northern forms is noticeable.

In the discussion Mr. Belt said that "Mr. Tiddeman and others had shown that the ice was piled up to the height of 2,000 feet above the sea in Lancashire ; Prof. Ramsay said it had over-ridden Anglesey from the north.

It could not have moved down nearly parallel to the coast unless the Irish Sea was filled with ice. This ice had left behind it stones from Cumberland and Scotland; along with these and other transported rocks were broken and worn shells, all of which it was admitted had not lived where they were now found, but had been brought from some other place. He contended that the same agent that had brought the foreign rocks had brought also the broken shells, and mixed together southern and northern species, and deep and shallow water forms."

1879.—Atkins, A. H. Black Band in the Drift.—*Mid. Nat.*, pp. 127, 159, 189, 211.

A peat-bed, 4 to 6 inches thick, was seen in the new railway cutting at Washwood Heath, on the Birmingham and Coleshill Road. It rests on a thin bed of white tenacious clay, and is covered by 12 feet of sand.

1879.—Beale, C. Drift in Walsall Cutting.—*Mid. Nat.*, pp. 226-227.

Adds some details to Mr. Twigg's paper, and calls attention to a cutting "on the Old Grand Junction line about half-way between Newton Road and Great Barr Stations. It is 60 ft. in height and half-a-mile in length. At 25 or 30 ft. above the rails pebbles of coal are found."

1879.—British Association Report: Erratic Blocks Committee.

Sheffield Meeting: Seventh Report.—Erratic blocks have been found at remarkably high levels for the Midland district, of 750 feet, upon Frankley Hill. The writer of this report (H. W. Crosskey) examined them in company with Prof. Bonney and Mr. W. Mathews.

In a cutting of the new Halesowen Railway passing through Frankley Hill, the following section has been exposed:—

Permian clay.
Sand of clayey texture.
Yellowish sand.
Greyish sandy clay, with Bunter pebbles.
Clay, somewhat sandy.

The heights of these various beds are very irregular throughout the section, which is itself about 60 feet in depth.

The Permian sandstone is exposed at one point in the section, and fragments of it are scattered through the sands and clays. Erratic blocks are rare in the sands and clays of the cutting itself; one only, indeed, a greenstone, was noticed at the time of our visit, although doubtless they occasionally occur. No part of this section can be called a boulder-clay, if by boulder-clay be meant either a clay formed beneath land ice, or a clay carried away by an iceberg and deposited over the sea-bottom as the berg melted or stranded. The various sands and gravels present all the appearance of a "wash" from older beds, effected during the depression and subsequent upheaval of the present land surface. They are neither compactly crowded

with erratics, nor are any grooved and striated fragments of local rock heaped irregularly together. The way in which the pieces of native rock are scattered through the beds does not indicate any other force than that which would be exerted by the ordinary wash of the waters during the movements just mentioned. The presence of a few erratics shows that the wash must have taken place beneath the waters of a glacial sea over which icebergs floated.

These beds appear to have been formed in the earlier rather than the later part of the glacial epoch. In a field *on the summit of the section* a large number of erratics is to be seen which have been taken from a surface drain. These erratics constitute a group of allied rocks evidently from one district. Among those observed (undoubtedly, however, a large number must be concealed beneath the soil) twenty were felsites, two were basalts, one was a piece of varied quartz, and another a Welsh diabase. Professor Bonney makes the following remarks on these boulders:—"The basalts are very little, if at all, decomposed, such as might have come from one of the basalts of post-carboniferous but pre-triassic age at Rowley, Pouk Hill, or the Clee Hill. There is no reason, however, for assigning them to the first or second of these localities; with the third I am not familiar. The "greenstone" is remarkably like several that I have seen in Wales as, for example, in the vicinity of the northern end of Llyn Padarn, from which locality, however, it is not likely to have come. If examined microscopically it would doubtless be found to be composed of a triclinic felspar, augite, and possibly olivine with some chlorite. Thus it may be called a diabase. The felsites have a considerable semblance one to another. They are of a greyish colour, weathering to a paler tint. They present occasionally indications of fluidal structure and flow brecciation, some looking rather slaggy, as if from the outer part of a flow, and I think they have been derived from this and not from an intrusive boss. I feel certain they are from Wales, and are of Lower Silurian age, but whether from the inter-bedded volcanic rocks of the Llandeilo or the Bala series I am not sure. One would expect them to come from the Arenig district. I have seen nothing like them in the Lake District."

Two of the felsites are of considerable size, the larger being 4 × 4 × 2 feet. Similar blocks may be traced almost to the summit of the hill. One felsitic block opposite the Yew Trees is $4\frac{1}{2} \times 3 \times 2$ feet. The height of these boulders above the sea is remarkable for the district, their highest level being about 750 feet. This fact indicates a corresponding depression of the land, since no Welsh glacier could have travelled over hill and down dale to this summit level. To render any such glacier work conceivable, the Welsh mountains must have stood at a height beyond any point for which there is the slightest evidence. This group of boulders on the summit of Frankley Hill appears to have been dropped by an iceberg travelling from Wales, upon the top of the clays and sands exposed in the railway cutting, at a time when the land was depressed at least to the extent of 800 to 1,000 feet. In the clays and sands upon which the summit group of erratics rest, we must have beds belonging

to an earlier date than the *close* of the glacial epoch, and the erraties in the cutting must be diseriminated from those left at the higher level.

Staffordshire.—The following, among the innnmerable erratic blocks seattered over the central part of the Midland District, deserve a speeial reeord, in addition to those described in previous Reports :—

1.—A boulder of felsite in the brickyard at the bottom of Oak Street, Wolverhampton. This boulder is of an oblong form, and measnres $11 \times 3 \times 3$ feet for a considerable portion of its length, although tapering in a somewhat irregular manner towards its ends. On the upper surfaee are rude and rough groovings running in all directions, and doubtless produced by the plough ; but one of the sides exposed is flat and smooth, and is covered with parallel striae, affording an extremely fine example of glacial action. The clay by which it is surrounded contains many more or less rounded pieees of granite, as well as of felsite, flints, together with quartzite and other pebbles from the Bunter beds. The large felsite ice-marked boulder was probably *dropped upon* the clay in which it rests, this clay itself being composed of the material brought by one of the earlier icebergs and intermixed with material of more local origin by the currents prevalent during the movements of the sea-bottom at a later period.

In the immediate neighbourhood is a surface boulder of granite $3 \times 3\frac{1}{2} \times 2$ feet. The grouping of these surface boulders needs to be carefully observed, as distinguished from the accumulation of blocks of all kinds in the sands and clays upon which they rest, or into the heart of which they have fallen.

2.—An erratic block of slate situated in a field near the Fox Inn, on the road to Trescott. This block has split into two pieces, the larger piece measuring $11\frac{1}{4} \times 3\frac{1}{4} \times 3\frac{1}{2}$ feet, and the smaller $9\frac{1}{4} \times 3 \times 3$ feet. It originally rested upon the surface, but some years ago it was buried, in order to utilise the land for agricultural purposes. An excavation was recently made (at the instance of the Dudley and Mid. Geol. Soc.) that it might be examined. This is the largest block of slate that has yet been seen in the district, and it is associated with very numerons boulders of granite and felsite.

3.—Mr. E. B. Marten has called attention to a boulder recently discovered by Mr. Beale in a watercourse running nearly due N. and S. near Moseley Hole, and the Wolverhampton, Willenhall, and Walsall turnpike road, and an accommodation road across the collieries from the Osier Bed Furnaces and Slow Lane to Bilston. It is in the line of the third *h* in the words "Stow Heath Furnace," and the letter *P* of "The Plough," on the one-inch Ordnance Map, No. 62, S.W., Lichfield. The boulder is composed of granite, and measures about $4\frac{3}{4}$ feet every way. Its weight is probably about three tons. Its shape is subangnlar, the angles being, with one exception, slightly rounded, but this exception is as sharp and clean as though the block had just been detached from its parent rock. The soil in which the boulder occurs is of a gravelly and sandy nature, containing some pebbles bearing the well-known indentations peculiar to, and characteristic of, the pebble bed of the Bunter. Its height is 420 feet above sea level.

4.—At Manor Green, half-a-mile S. of Walsall, in a field near the Old West Bromwich Road, a block of felsite stands erect like a pillar. It measures $4\frac{1}{2} \times 4\frac{1}{2} \times 2$ feet.

1879.—Brodie, Rev. P. B. Quartzite Pebbles in the Drift of Warwickshire.—*Proc. Warwickshire Field Club*, p. 28.

1879.—Clarke, J. E. On the Triassic Boulder, Pebble, and Clay Beds at Sutton Coldfield.—*Proc. Yorkshire Geol. Soc.*, pp. 66-72.

1879.—Ingram, Rev. A. H. W., M.A. Superficial Deposits in the neighbourhood of Evesham.—*Quart. Journ. Geol. Soc.*, p. 678.

Flints at Evesham 120 feet above the Avon, also at Moreton-in-Marsh. Chalk occurs in a cutting at Aston Magna.

1879.—Mackintosh, D. Distribution of Erratic Blocks in West of England and East of Wales.— *Quart. Journ. Geol. Soc.*, pp. 425-455 ; with map.

"The truly wonderful concentration of boulders west and north of Wolverhampton. . . . They must have been carried by a sheet of land-ice fifteen miles in breadth, or by great masses of floating ice ; and the blocks must have fallen where the air or the water was sufficiently warm to melt the ice so as to prevent their further transportation ; for they terminate too abruptly, and on too extensive a scale, to admit of any other supposition."

"The Eskdale granite which went to Burton (Shropshire) must have *crossed the course* of the stream of Criffel granite which went to Wolverhampton." The author considers that the big "10 foot" boulder in the Oak Street brickyard (Wolverhampton) is an Arenig felstone. The Arenig felstone boulders of the Clent and Lickey Hills are described as an "overshot load."

Some doubtful striae (N.W. to S.E.) occur on Haughmond Hill.

This paper abounds in valuable facts, and should be read with care.

1879.—Peach, B. N., and Horne, J. The Glaciation of the Shetland Isles.—*Quart. Journ. Geol. Soc.*, pp. 778-811 ; with one plate.

The Scandinavian ice-sheet invaded the islands from the N.E. But as it crossed them it swung round to the N.W., owing probably to the outward pressure of ice from the Scottish mainland. There are no gravel kames or raised beaches. Local glaciers lingered after the main ice-sheet had passed away, their presence being attested by their numerous moraines pointing in all directions.

1879.—Twigg, G. H. Drift of Railway Cutting near Walsall. *Midland Naturalist*, pp. 201-202.

The cutting is on the new loop line connecting the South Staffordshire Railway with the Grand Junction line, and occurs where the line is crossed by the main road from Walsall to Wednesbury. Red to grey clays are seen mingled with gravels and sand. Fine-grained and decomposed basalt boulders are found along with Carboniferous Sandstone blocks up to 2 feet in diameter. Thin bands of drift coal are seen.

1879.—Usher, W. A. E. The Pleistocene History of Cornwall.—*Quart. Journ. Geol. Soc.*, p. 6.

No glaciation in Cornwall [nor in Devon]; nor any submergence over 60 feet.

1880.—Andrews, W. Superficial Deposits near Coventry. (Three feet of stiff red clay lies on the Permian Sandstone. Considers this due to the denudation of the Permian *in situ.*)—*Proc. Warwickshire Field Club*, p. 1.

1880.—Aveline, W. T. Geology of the Country around Nottingham. *Geological Survey Memoir*: 2nd ed.

The drift here is largely local, the gravels and sands being in great part derived from the Bunter pebble beds; but many chalk-flints occur in places. There is a large boulder of dark trap rock, 4½ by 2 by 3 feet, on the road leading from Kirkby Forest to Sherwood Place.

1880.—Bonney, Professor T. G. Pebbles in the Bunter Beds of Staffordshire.—*Geol. Mag.*, Decade II, vol. VII, pp. 404-407.

Refers to Mr. Pereeval's collection of fossiliferous pebbles "in the Jermyn Street Museum" obtained from the Moseley cutting.

1880.—Dawkins, W. B. Early Man in Britain and his place in the Tertiary Period.—Macmillan and Co.

A valuable and well-illustrated book, which may be regarded as a sequel to the same author's well-known work on "Cave Hunting."

1880.—British Association Report: Erratic Blocks Committee.

Swansea Meeting: Eighth Report.—In Leicestershire Charnwood Boulders occur near Market Bosworth, and at Carlton, &c.

1880.—Crosskey, Rev. H. W. Ice Remains in the Midland District.—*Proc. Dudley Geol. Soc.*, pp. 19-20.

1880.—Harrison, W. J. Another Boulder.—*Midland Naturalist*, p. 92.

A Mount Sorrel granite boulder weighing about 1½ tons lies in a field between the villages of Ratby and Glenfield, and about four miles west of Leicester. Its height above sea level is 270 feet. It is six miles S.S.W. of Mount Sorrel.

1880.—Jeffreys, J. Gwyn. On the Occurrence of Marine Shells of existing species at different heights above the present level of the sea.—*Quart. Journ. Geol. Soc.*, pp. 351-355.

Gives a detailed list of the 63 species of marine organisms found in the Moel Tryfan gravels. The deposit was a raised beach.

1880.—Mackintosh, D. Correlation of Drifts of North-West of England with those of the Midland and Eastern Counties. *Quart. Journ. Geol. Soc.*, pp. 178-188.

At Shrewsbury and Berrington the Boulder-clay (except for the absence of lime) is identical in appearance with the Upper Boulder Clay of Cheshire and Lancashire.

An angular drift of syenite occurs around the Malverns, and between those hills and the Severn; this overlies all other deposits, and occurs at both high and low levels.

The author regards the district between Wolverhampton and Stafford as the meeting-ground of the erratics from the N.W. and the N.E.

1880.—Peach, B. N., and Horne, J. The Glaciation of the Orkney Islands.—*Quart. Journ. Geol. Soc.*, pp. 648-663; with two charts.

All the evidence confirms that obtained in the Shetlands (see paper by the same authors in 1879).

The general movement of the great ice sheet which crossed the Orkneys was from the S.E.

Fragments of marine shells are numerous throughout the Boulder-clay; but "though we examined the section with the utmost care we did not succeed in dislodging a complete shell; indeed, so worn are the fragments that it was with the utmost difficulty that we obtained specimens sufficiently well preserved for determination. Nearly all the fragments are smoothed and striated, like the stones in the Boulder-clay." The Boulders include many rocks from the Scottish mainland, with one or two which may be of Scandinavian origin.

1880.—Wood, S. V., jun. Newer Pliocene Period in England.—*Quart. Journ. Geol. Soc.*, pp. 457-529; with one plate.

Groups the Frankley Hill "water-deposited sands and sandy clays, with erratic blocks derived from Wales" with his Norfolk "Lower Glacial" beds (p. 476).

In the California section, the bottom clay is assigned to the Lower Glacial; and the "india-rubber clay" is considered to be the equivalent of the Great Chalky Boulder Clay (p. 490).

1880.—Wyley, A. Clay-pit near Lappal Tunnel.—*Proc. Dudley Geol. Soc.*, vol. IV, p. 50.

Notes of Field Meeting on October 21st, 1879:—

In the last Clay-pit visited on that day, a curious intrusion of marl was pointed out, very like the ordinary Red Marl forming the upper portion of the New Red Sandstone, but it is seen here among the coal-measure clays of the small spur of the coalfield, which juts out between two faults towards the east, at the south-west corner of the South Staffordshire Coalfield.

A subsequent visit led to the conclusion that these marls were boulder-clay, though largely derived from the red marl of the neighbourhood, which gives them very much the appearance of the red marl itself, but the interstratified beds of fine sand and seams of fine gravel containing pebbles of syenite, granite, and felspathic traps of various kinds, are foreign to the neighbourhood, though some of them may be secondarily derived from the Permian breccia of the Lickey or Clent Hills, which is traceable to within a mile of the beds in question. All goes to prove them to be of glacial age. Whether the contortions, &c., are caused by the grounding of icebergs, or by the thawing of included ice-lumps, the author does not attempt to decide.

1881.—British Association Report: Erratic Blocks Committee.

York Meeting: Ninth Report.—Mr. Mackintosh writes—"Many large boulders from the Arenig Mountains have found their way through the gap in the Minera mountain range which is traversed by the road leading from Mountain Lodge (W. of Ruabon) to the World's End (N. of Llangollen).

1881.—Brodie, Rev. P. B. Pebbles in the Drift in Warwickshire. *Quart. Journ. Geol. Soc.*, pp. 430-436.

Records the finding of sixteen species of fossils in the quartzite, &c., pebbles of the Drift in Central Warwickshire.

1881.—Giles, Oliver. The Boulders of the Bromsgrove District.—*Proc. Bristol Nat. Soc.*, pp. 118-121.

Nearly the whole of the boulders of this district have been traced to the Arenig Mountains of North Wales.

One boulder at the Woodrow has been removed from a field into an adjacent lane; it is at corner of road to Lydyate Ash, and 858 feet above sea-level. It measures 81 by 33 by 18 inches. One block which lies in a lane near Finstal Park shows ice-markings.

1881.—Lucy, W. C. Notes on Rocks found in the Northern Drift Gravels.—*Midland Naturalist*, pp. 242-244.

Flints, chalk, &c., occur round Moreton-in-the-Marsh; Fossiliferous Silurian rocks on Limbury Hill (eight miles from Gloucester); and flint, granite, felstone, &c., near Gloucester.

1881.—Mackintosh, D. On the precise mode of Accumulation and Derivation of the Moel Tryfan Shelly Deposits; on similar high level Deposits along the Eastern Slopes of the Welsh Mountains; and on Drift Zones.—*Quart. Journ. Geol. Soc.*, pp. 351-369.

The shelly sands and gravels, with Eskdale granite, chalk-flints, &c., occur from 1,170 up to 1,350 feet above sea level. The edges of the laminae of the slates on which the gravels rest have been bent from N.W. to S.E., probably by the stranding of an iceberg. The shells may have lived where they are now found, or they may have been brought by floating ice.

Arenig boulders occur on Frondeg (1,500 feet), Cyrn-y-brain (1,830 feet), Moel Gamelin (1,900 feet); and near Frondeg the Arenig felstone dispersion meets the Eskdale granite dispersion.

1881.—Geikie, Jas. Prehistoric Europe. A Geological sketch. Stanford.

An important work, which supplements the first edition of the same author's fine book—"The Great Ice Age."

1882.—British Report Association: Erratic Blocks Committee.

Southampton Meeting: Tenth Report.—Mr. Woodall describes the "rough ground" in the North Sea 20 to 40 miles distant from the coast of Durham and Yorkshire. Blocks of Shap Granite and of Carboniferous Limestone are frequently dredged up here, and it is thought to be the moraine of "the giant glacier which descended the Tees Valley."

The Icknield Street (Birmingham) Section is described.

Rev. W. Tuckwell mentions the Stockton boulder, near Rugby, of Mount Sorrel granite, measuring 48 × 28 × 26 inches; height above sea level 289 feet.

Mr. W. J. Harrison records a boulder near Victoria Park, Leicester, which was composed of syenite, like that at Enderby and Croft, four miles *south* of Leicester. The block measured 3½ by 2 by 1½ feet, and was very angular.

Mr. Luff reports on Clun Boulders, one of which (a pebbly grit of the Plinlimmon group) lies at a height of 1,160 feet, and weighs over six tons. These blocks must have travelled almost due E. from the neighbourhood of Rhayader, &c.

1882.—Crosskey, Rev. H. W. Drift Section in Icknield Street, Birmingham.—*Proc. Birmingham Phil. Soc.*, pp. 209-216; with three plates.

The section was on the north-west slope of the New Red Sandstone between Key Hill and Hockley Hill. A great number of pebbles and stones occurred in a sandy clay, the whole drift being seven or eight feet in thickness. All the stones are either local or from the Berwyn and Arenig Hills; the largest erratic seen was 32 by 18 by 16 inches. The sandstone rock on which the Drift rested was greatly broken and disturbed, and large fragments of it had been torn off and were embedded in the middle of the Drift. The author correlates this drift with the Lower Boulder-clay seen at California, and assigns the cause to ice striking against the hill (inclining to the idea that it was the work of coast-ice floating from Wales during a submergence).

1882.—Harrison, W. J. Quartzite Pebbles in the Drift and Trias of Central England.—*Proc. Birmingham Phil. Soc.*, pp. 157-203.

Traces pebbles of quartzite northwards from the Thames Valley to the outcrop of the Bunter Conglomerate in Worcestershire, Staffordshire, and Nottinghamshire. To the south of this outcrop such pebbles are very abundant in the Drift, to the north of it they are rare or absent. The identity of the Drift quartzites with those of the Bunter is proved (*a*) by the presence of white indented spots on the exterior; (*b*) examination of thin sections under microscope; (*c*) the occurrence of a similar series of fossils in each (fossils which also occur in the pebble-bed—Bunter also—of Budleigh Salterton). The Bunter pebble-beds are in their turn referred to an ancient Land Axis which stretched across Central England from the Malvern to Charnwood, and of which outcrops still occur at the Wrekin, the Lower Lickey Hills, the Hartshill Range, Dosthill, &c.

1882.—Harrison, W. J. Geology of the Counties of England; and of North and South Wales.—Large 8vo, pp. 16, xxviii, and 346; with 106 woodcuts. Kelly and Co., London.

This book has (through no fault of mine) been long out of print. But the articles relating to each county will be found in Messrs. Kelly's well-known series of "County Directories."

The following extracts refer to the Midlands:—

Staffordshire.—"When we find irregular beds of sand or clay at the surface, containing fragments of granite, lias, oolite and other rocks, which must have travelled from a distance, and which are often striated and grooved, we assign them to the last Glacial Period, when ice masses from the north and west seem either to have descended as glaciers or sailed as icebergs over the whole of Central England. There is a great accumulation of travelled

blocks, often of great size, in the neighbourhood of Wolverhampton ; these include masses of felstone which must have come from the Arenig Mountains of North Wales ; and granites, like those of Eskdale in Cumberland and Criffel in the south of Scotland ; boulders of the Welsh rocks lie thickly, too, between Hagley and Bromsgrove."

WARWICKSHIRE.—"Scattered irregularly over the rocks we have been describing, there occur beds of sand, gravel, and clay. . . . Great masses of syenite, evidently torn off the rocks of Charnwood Forest, have been found near Rugby ; but generally the boulders are small, not exceeding a foot or two in diameter. Pebbles of Silurian rock are common, with chalk flints, quartz pebbles, &c. The locality and parent rock from which these extremely hard, well-rounded quartzite pebbles were derived, is a very interesting question ; almost everywhere in this county they are used for road-mending, and may be seen lying in heaps by the road side. About one pebble in ten thousand contains a fossil, usually a shell of some kind or other, and it is only by collecting a large number of these fossils that the question as to whence the pebbles have come, can be solved.

"Of still later age are the river gravels of the Avon, which have yielded at Rugby a fine jaw of an extinct species of *Rhinoceros*, and at Warwick and Leamington remains of the *Mammoth*, an extinct species of elephant."

Numerous other references to the Glacial Period and its conditions are contained in this book. To each county is prefixed lists of the geological maps, &c., of that county ; of the local scientific societies ; the muscums ; and of the principal geological papers, books, &c., which have been written concerning the county.

1882.—Jamieson, T. F. On the Crag Shells of Aberdeenshire, and the Gravel Beds containing them.—*Quart. Journ. Geol. Soc.*, pp. 145-159.

The gravel eskers have glacial clays below and above them. The "shelly material occurs generally in the form of fine pounded debris and small worn crumbs, with here and there a larger bit, generally a hinge of *Cyprina*, *Astarte*, or *Venus*." According to the Messrs. S. V. Wood, out of the 25 species of shells met with about one-half are extinct. Most of the shelly gravel lies at heights above sea-level of from 100 to 200 feet.

1882.—Mackintosh, D.—Additional discoveries of High-level Marine Drifts in North Wales, with remarks on Driftless Areas. *Quart. Journ. Geol. Soc.*, pp. 184-196.

The drift-zone between Minera and Llangollen Vale is described.

1882.—Reade, T. M. On the Chalk-masses or Boulders included in the Contorted Drift of Cromer, their Origin and Mode of Transport.—*Quart. Journ. Geol. Soc.*, pp. 222-238.

The boulders were brought by ice-rafts, and were derived from cliffs close at hand.

1882.—Reid, C. Geology of the country around Cromer (Geological Survey Memoir).—8vo, pp. 143, with 13 woodcuts. Eyre and Spottiswoode; price 6s.

"The chief interest of [the Cromer Cliffs of the Norfolk coast] lies in the coast sections where is exhibited perhaps the finest sections of Glacial Drift in the country." [H. W. Bristow.]

The cliffs rise to a height of 250 feet and are mainly composed of Glacial clays, sands, and gravels (including enormous detached masses of chalk) which have been wonderfully contorted by lateral pressure, due—as the author believes—to the agency of the land-ice shown by Scotch and Scandinavian geologists to have covered a large portion of northern Europe during part of the Glacial epoch. The ice-flow was from the north-east. "The extreme shallowness of the North Sea would cause it to be entirely filled with ice, which, flowing over or abutting against the older drifts, contorted them in the way we now see."

1882.—Wood, S. V., jun. Newer Pliocene Period in England; part II.—*Quart. Journ. Geol. Soc.*, pp. 667-745; with sections.

Of this lengthy and detailed paper it is almost impossible to give a brief abstract; it must be read as a whole.

1883.—Atkins, A. H.—Glacial Markings in the Red Marl.—*Midland Naturalist*, pp. 230-232; and *Report Birm. Nat. Hist. and Micro. Soc.* for 1883, pp. 1-3.

Patches of clay (similar to that at California) occur at Washwood Heath and Tysull. At Sames's brickworks (situated on the east of Birmingham at the junction of Garrison Lane with Cattell Road) we find a bed of tenacious clay over 20 feet in thickness resting upon Keuper Red Marls and not easy at first to distinguish from them. At the junction is a band of hard shale or sandstone called *roche*, which was seen to be smoothed and polished after the clay above had been removed. Believes that the upper clay is the result of ice action.

1883.—British Association Report: Erratic Blocks Committee.

Southport Meeting: Eleventh Report.—Professor Bonney reports on the Cannock Chase boulders as follows:—"Erratic blocks are so rare on or near the northern edge of Cannock Chase, in the vicinity of the Trent, that the following instances are worth recording: In the immediate neighbourhood of Rugeley I only know of one erratic; as a rule one does not hesitate to refer all pebbles to the Bunter Conglomerate, directly or indirectly. That formerly stood in an open part of a street on the south side of the town, where the name 'Crossley Stone' is still on record. Some years since it was broken up, and the fragments removed to the neighbourhood of a canal wharf

on the opposite side of the town. There are now two fragments, partly buried in the ground; the larger measures $4\frac{1}{2} \times 4$ feet, and is at the thickest part 14 inches; the other piece is a little smaller. The first two dimensions, as far as I can remember, represent the area of the original stone. The rock is a compact grey felstone, a typical example of a boulder of the 'Arenig dispersion.'

"In the village of Colton, about one mile from the Trent, and on its left bank, boulders appear to be more common. Four are used as guards at the angle of a little bridge near the church; one is rudely triangular, each side being about $2\frac{1}{2}$ feet, and the thickness about 15 inches; a second is about $3 \times 1\frac{3}{4} \times 1\frac{1}{2}$ feet; a third rather smaller. These are a grey granite, like that from Criffel. The fourth boulder is rather oval, its longest diameter being about 3 feet. This is a moderately coarse syenite, consisting of pinkish felspar and green hornblende, with a little quartz—I believe, a Scotch rock; these, of course, are not *in situ*, but cannot have been brought from far. Built into walls, used as steps, or lying about in or near the village, are several other boulders of smaller size, commonly not exceeding $1\frac{1}{2}$ feet in longest diameter. The grey granite (Criffel) is the commonest rock; but I noticed two of the 'Arenig' felstone, one also of a greenish-grey felspathic grit, some of the (not numerous) quartz grains being of a bluish colour—probably from Wales—and one (at the crossing of two roads in the village) a minutely crystalline syenite or hornblendic granite, reddish felspar being the predominant mineral. I have seen the rock before in collections of erratics. I believe it is Scotch, though I think there is a rock something like it in the Carrock Fell region. It is certainly of Northern origin."

Mr. Horace Pearce (of Stourbridge) records the following Midland Boulders:—

(1) Felstone, 10 feet in circumference, in Clent parish, at junction of road from Stourbridge to Bromsgrove, with by-road to Clent Hills. Another felstone block lies opposite to it.

(2) Granite: just beyond the N.W. corner of Highgate Common, Staffordshire, near a large Spanish chestnut tree; circumference, 11 feet 7 inches.

(3) Group of granites and felsites extending from Claverly to Bridgnorth.

(4) Felsite, 9 feet 4 inches in circumference, near Waystone, Abbot's Castle, in boundary road between Staffordshire and Shropshire.

(5) Vein Quartz, 5 feet in circumference, in boundary road near Halfpenny Green, Salop.

(6) Group of boulders near Gospel Ash, Staffordshire, comprising blocks of hornblendic granite, poor in quartz, and said by Professor Bonney to be indistinguishable from specimens from Buttermere; and compact felsite and mica syenite.

Mr. Luff states that granite boulders occur on the north flank of the Longmynd.

1883.—Browne, A. J. Jukes. On the relative age of certain River Valleys in Lincolnshire.—*Quart. Journ. Geol. Soc.*, pp. 596-610.

The map on p. 600 shows how the Chalk Wolds divide the Purple and Hessle Clays on the east, from the Great Chalky Boulder Clay on the west.

1883.—Crosskey, Rev. H. W. Grooved Blocks and Boulder Clays of Rowley Hill.—*Proc. Birm. Phil. Soc.*, pp. 459-472; four plates.

Highest point of the Rowley Hills is about 890 feet above sea-level. These hills are composed both of fine-grained basalt, and of a softer basaltic rock locally called "roche." Boulder-clay full of *local* basaltic rocks, and from 2 to 8 feet in thickness, is seen at several points on the hills. The blocks are often grooved and polished; and at the Rowley Hall Quarry there is a striated pavement, where the predominant direction of the grooving is from N.W. to S.E. Mentions that Mr. W. J. Harrison has found a boulder of the Rowley basalt at Harborne, and many others at Foundry Road, Birmingham, but reserves the general distribution of these boulders for further investigation. In conclusion, the author thinks that "for a certain time during the submergence of the land which took place in the Glacial epoch, Rowley Hill was an island. In the winter it would be capped with snow and ice. This capping of snow and ice would glide steadily downwards, so producing the grooves, &c., and form a limit of ice first along the coast-line. The ice-foot breaking off in summer would float away fragments of the rock and convey them to the places where they are now found."

1883.—David, J. W. E.—Glacial Action in South Brecknockshire and East Glamorganshire.—*Quart. Journ. Geol. Soc.*, pp. 39-54.

The district described includes Cardiff, Merthyr Tydvil, &c.

The whole area has a *moutonnée* aspect: all the erratics are of local origin, except that chalk-flints occur in the Ely Valley. Unstratified boulder-clay from 30 to 100 feet thick runs up to a height of 1,200 feet above sea-level. *Striae* are of common occurrence, and their general direction is from N. to S., but they trend to S.E. in the Rhondda and Taff Valleys at lower levels.

1883.—Harrison, W. J.—Ice-grooved Boulders.—*Midland Naturalist*, pp. 277-278.

Refers to grooves which pass round the edges of boulders, and records the occurrence at Criccieth of a boulder "built into a wall near the school, and just at the foot of the little hill called Dinas," which shows such grooving.

1883.—Mackintosh, D. Traces of an Interglacial Land-surface at Crewe.—*Proc. Liverpool Geol. Soc.*, pp. 267-269.

At the Railway Station finely-laminated clay rested on quicksand, and graduated upwards within a foot, vertically, into typical upper boulder-clay,

about ten feet in thickness. In the "leaf-clay" a foram of shallow-water species occurred, with plant-remains including rootlets, &c.

1883.—Reade, T. M. On the Drift-beds of the North-west of England and North Wales. Part II; with an Appendix by D. Robertson.—*Quart. Journ. Geol. Soc.*, pp. 83-132; with map and sections.

No geological subdivisions can be distinguished: all the clays and sands were deposited on the sea-bottom during a great submergence. The erratics were carried by icebergs; rivers also brought down much debris.

In the discussion Prof. Boyd Dawkins said that Antrim Chalk had been found at Ironbridge on the Severn.

1884.—Andrews, W. Chalky Boulder-clay in Central Warwickshire.—*Proc. Warwickshire Field Club.*

Describes the Berkswell cutting: 30 feet thick blue clay with chalk, &c. Two other patches occur near Coventry.

1884.—Beale, C. The Basalt of Rowley Regis. Part I. The Occurrence of Grooved and Striated Stones on the Rowley Hills.—*Midland Naturalist*, pp. 109-112.

Part II. The Roche and Clay-marl.—*Midland Naturalist*, pp. 126-131.

1884.—Beale, C. Granite Boulder found in a Newly-formed Watercourse at Stow Heath, Bilston.—*Proc. Dudley Geol. Soc.*, p. 18.

1884.—British Association Report: Erratic Blocks Committee.

Montreal Meeting: Twelfth Report.—Mr. F. W. Martin describes the drift sections exposed during the process of enlarging the West Suburban Railway, which runs from New Street Station, Birmingham, through Edgbaston to King's Norton, a distance of about 5½ miles. The cuttings generally are through drift, composed of varying proportions of sand, clay, and gravel, resting on a fairly regular surface of the New Red Sandstone rock of the district. Except near King's Norton, this drift, as far as it has been exposed by these excavations, is entirely free from erratic blocks, the largest stones not averaging more than 3 or 4 inches in diameter.

At a point on the railway near the village of Stirchley, about 4½ miles from Birmingham, the drift is composed of a tenacious marly clay unstratified, and with very sparsely scattered Bunter pebbles. A few erratic blocks (presently to be catalogued), averaging in size about 18 by 12 by 12 inches, were found, mostly of a felsitic rock. About 50 yards to the south of

this point, the nature of the drift changes to a dark-red clay with angular gravel, which gravel consists mostly of fragments of broken-up slate. This angular gravel overlies a dark red clayish gravel made up of Bunter pebbles, but having no angular fragments. Below these gravels is a band of pale-coloured loose sand about 2 feet thick, and much contorted. Below this again is a sandy, gravelly clay resting immediately upon a green shale or marl, the basal bed of the Keuper. All these gravels contain erratic blocks in large numbers.

About a quarter of a mile from this point a few erratic blocks have been obtained from a matrix of very sandy clay, interstratified with beds, about 2 or 3 inches thick, of a more gravelly clay, and containing rounded pebbles, and angular fragments of coal shale, carboniferous grit, &c., besides small blocks of the basal rock of the Keuper above mentioned.

At this point, in a dell at the side of the railway, is a large felsitic boulder (No. 2 in the subjoined list) measuring 75 by 57 by 45 inches ; only about one-third of it is visible above ground, the rest being buried in clay. This was cleared and photographed.

Near the junction of the new railway with the main line to Gloucester is another large boulder (No. 1 on subjoined list), measuring 108 by 96 by 36 inches, lying about 9 feet below the surface.

The erratic blocks found in these gravels vary in cubic capacity from 1 to 216 cubic feet, and include shales, slates, ashes, felsites, pure quartz, carboniferous sandstone, and grit, though the majority of them are felsitic, and derived from the Arenig and Berwyn Hills district. A few of these blocks, more especially the slates, retain ice-markings and smoothings, but the majority have rough surfaces."

Description of twelve boulders (by Dr. Lapworth) is appended. The largest boulder (No. 1) is a "rough, bluish-green, felspathic ash, with crystals of felspar. No. 2 is a "rough amygdaloidal or brecciated green felstone." Neither show any striae or smoothing. The next eight boulders are felspathic ashy rocks (probably 'Arenigs'). No. 11 is a "well-bedded striped mudstone flag, probably of Silurian age" (size 18 by 15 by 3 inches). No. 12, "fragments of slate showing ice-groovings and smoothing; probably Silurian blue mudstone from the Berwyn Hills.

1884.—Crosskey, Rev. H. W. Some additions to the Fauna of the Bridlington (Post Tertiary) Beds.—*Proc. Birmingham Phil. Soc.*, vol. II, pp. 373-379.

1884.—Crosskey, Rev. H. W. Note on Ice-marked Boulders, illustrating the Grooved Blocks of Rowley Hill.—*Proc. Birmingham Phil. Soc.*, pp. 69-72 ; with one plate.

Describes a boulder found embedded in the Saas Fée moraine which must have been grooved by ice passing over it while it was so embedded. The grooves run up one side of the boulder and down the other. The paper

includes a description of a greenstone boulder with similar deep grooves running right round one corner, found by Mr. W. J. Harrison at Criccieth.

1884.—Martin, F. W. Geological Sections along the West Suburban Railway from Birmingham to King's Norton. *Proc. Birmingham Phil. Soc.*, pp. 257-268; with plate.

The length of the line was 5¼ miles, over the New Red Sandstone. The drift resting on the live rock is "in the main a firm dark-coloured gravel," about 15 feet in thickness. Beyond Granville Street "we find long thin blocks of Sandstone (Trias) broken from the rock below, and wedged tightly into the gravel matrix," as in the Icknield Street section. Contorted clays and sands are seen at the Somerset Road Station; and peat occurs under gravels, &c., at Raddlebarn Lane. Nearing King's Norton we find boulder-clays of local origin. Large felstone erratics (Arenigs) occur here, one measuring 9 × 8 × 3 feet.

1884.—Symonds, W. S. The Severn Straits with Notes on Glacial Drifts, Bone Caverns, and old Glaciers, some within reach of the Malvern Hills.—Tewkesbury, pp. 150.

1884.—Watts, W. W. Geology of Lilleshall Hill and its immediate vicinity.—*Report N. Staff. Nat. Field Club.*, pp. 45-47.

1885.—British Association Report: Erratic Blocks Committee.

Aberdeen Meeting: Thirteenth Report.—Mr. Luff continues his report on the Boulders of the Clun district. Mr. R. T. Andrews (of Hertford) reports that igneous rocks are absent from the drift of the south of Herts: sandstones, grits, and "pudding-stone" blocks are common.

1885.—Browne, A. J. Jukes. The Boulder-clays of Lincolnshire.—*Quart. Journ. Geol. Soc.*, pp. 114-132.

Two types of glacial clay occur in this county: (1) a "grey or blue series" = the Chalky Boulder-clay; (2) a "brown series" = the Purple and Hessle Boulder-clays. The former occurs only on the *western* side of the Chalk Wolds: the latter mainly on the east of these hills. He thinks that the Chalky Clay is the older of the two series.

1885.—Lamplugh, G. W.—On Ice-grooved Rock Surfaces near Victoria, Vancouver Island; with notes on the Glacial Phenomena of the neighbouring region, and on the Muir Glacier of Alaska.—*Proc. Yorks. Geol. and Poly. Soc.*, pp. 57-70; with plates.

Gives valuable details concerning rock-grooving, *roches moutonnées*, &c. "Near the foot of the Muir Glacier" a great mass of ice directly overlaid bedded sands and gravels without disturbing them.

1885.—Mortimer, J. R. The Unwaterworn Chalk-gravel on the Yorkshire Chalk Hills.—*Proc. Geol. Assoc.*, pp. 287-298.

Occurs mostly at elevated points on the sides of valleys. Due to ice-pressure.

1885.—Reade, T. M. Notes on the Southern Drift of England and Wales.—*Proc. Liverpool Geol. Soc.*, pp. 216-233.

Warwick.—At the Haseley Waterworks, patches of gravel rested on the Keuper marls, and were overlaid by white and yellow siliceous sands, 17 feet, with 8 feet of clayey quartzose gravel on top. Much gravel occurs near Kenilworth Station. "I was struck with the absence of boulder-clay in Warwickshire, and its replacement with sand and gravel."

1885.—Reade, T. M. The Drift Deposits of Colwyn Bay.—*Quart. Journ. Geol. Soc.*, pp. 102-107.

There is "till" at the bottom containing Welsh rocks, overlaid by Boulder-clays and sands containing Lake District and Scotch rocks.

1885.—Ricketts, Dr. C. On some Erratics in the Boulder-clay of Cheshire, and the conditions of climate they denote.—*Quart. Journ. Geol. Soc.*, pp. 591-598.

"Icebergs and floes ploughed their way (across the Irish Sea) into the Bay of Liverpool, distributing their load of boulders in the passage." Believes that the boulders, &c., which so frequently show signs of *weathering* were so affected since their deposition in the boulder-clay, while they were exposed during occasional retreats of the glaciers.

1886.—Aulton, A. D. Excavations in Walsall. — *Midland Naturalist*, pp. 322-323.

1886.—British Association Report: Erratic Blocks Committee.

Birmingham Meeting: Fourteenth Report.—Dr. Crosskey made a special report "On the Glacial Phenomena of the Midland District," which is printed in full; pp. 224-226.

1886.—Crosskey, Rev. H. W. Glacial and Post Tertiary Deposits. *British Association Handbook of Birmingham*, pp. 248-253.

"Glacial striæ upon the surface of the rock have been noticed at Weoley Hill Quarry, close to California. The removal of a mass of clay, sand, and

gravel exposed a distinctly striated surface of hardened Bunter Sandstone. The polished surface dips towards the south-west, in which direction the principal striae run, although there are several cross striae. The altitude is 520 feet above sea level."

"There is also at Rowley Hill Quarry a kind of platform, capping the solid mass of basalt, which is almost entirely composed of blocks with smoothed and grooved surfaces, stiffly embedded in clay. . . . No other explanation than that the grooves were the work of moving ice can account, I think, for their excellent polish, their frequent parallelism, their adaptation to the hollows and protuberances of the blocks they cross, and their predominant trend from north-east to south-west. The absence of erratics from the boulder-clay in which the grooved basaltic blocks are embedded is evidence of local ice action at Rowley Hill."

"A boulder-clay of a typical kind, has been exposed at a brickyard at the bottom of Oak Street, Wolverhampton. This clay contains an extraordinary number and variety of erratic blocks, without question from the Lake District and South of Scotland; a few flints, together with pebbles, from the Bunter beds. One of the sides of a boulder of felsite, measuring $11 \times 3 \times 3$ feet, is flat and smooth, and covered with parallel striae. The sands and gravel rising in small hillocks near the Cemetery, and slightly covering the clay of the pit, are probably Middle Glacial."

1886.—Crosskey, Rev. H. W. Glacial Phenomena of the Midland District.—*British Association Report*, pp. 224-226.

A general statement of the problems awaiting solution. Points out facts which appear to indicate a succession of events during the glacial epoch: First land-ice; then submergence with floating-ice; and lastly a re-elevation.

1886.—Deeley, R. M. Pleistocene Succession in the Trent Basin. *Quart. Journ. Geol. Soc.*, pp. 437-480.

Describes the Great Chalky Boulder-clay as having "Pennine" (*i.e.* northern) boulder-clays both below and above it; but beds of gravel or sand come between all these boulder-clays. Altogether eight divisions in the Drift are recognised; four being boulder-clays, and the remainder sands or gravels.

1.—*The Early Pennine Boulder-clay* is seen at Oadby near Leicester, and in the Valley of the Wreak. It contains *no* Oolitic or Cretaceous rocks.

2.—*The Quartzose Sand* consists of fine yellow or reddish false-bedded sand or gravel. It is seen in the valleys of the Soar and the Wreak, and at Grantham and near Nottingham.

3.—*Middle Pennine Boulder-clay.* "Formed in the path of great glaciers which came down the valleys of the Derwent, Wye, and Dove, and crossed the partially-submerged valley of the Trent." At Burton-on-Trent this clay contains erratics probably from Cumberland and Scotland.

4.—*The Melton Sand* is marked by the appearance of flints in great numbers, It is typically developed round Melton Mowbray.

5.—*The Great Chalky Boulder-clay* passed up the Trent Valley to Hanbury, north-west of Burton-on-Trent; and southwards past Leicester. There is an outlier at Abbott's Bromley, and another at Chellaston.

6.—*The Chalky Gravel* is very widely spread.

7.—*Interglacial River-gravels* give "the first sign of subaerial erosion." They are rusty-red and compact, and occupy terraces along the valley of the Trent, &c.

8.—*Later Pennine Boulder-clay* is formed largely of subjacent rocks. It occurs at Wolverhampton and elsewhere in Staffordshire, and in South Derbyshire and Notts.

The author believes that the boulder-clays were formed by—some beneath and some in the sea in front of—the agency of glaciers: the sands and gravels are mainly marine deposits.

1886.—Evans, A. T. The Fossiliferous Bunter Pebbles contained in the Drift at Moseley, &c.—*Brit. Assoc. (Birm.) Report*, pp. 627-628.

With the quartzite pebbles are a few fragments of Silurian limestone, carboniferous chert, carboniferous sandstone, and Llandovery Flags; also flints, granite, basalt, quartz conglomerate, and intensely hard pieces of a black siliceous rock. They vary in size, but few exceed a foot in diameter. Brachiopods, lamellibranchs, cephalopods, gasteropods, annelids, plants, crinoid stems, and fragments of trilobites have been found in the quartzites, &c., but they are of very rare occurrence (perhaps one pebble in 3,000 is fossiliferous).

1886.—Harrison, W. J. Faults in the Drift (at Kibworth, Leicestershire).—*Midland Naturalist*, p. 138.

Kibworth is eight miles S.E. of Leicester. The glacial sands are there worked in pits 40 feet deep, and are distinctly faulted, although the "throw" of the faults does not exceed a few feet. The height is about 376 feet above sea-level. In a pit 200 yards N.E. of the railway station the sands were contorted, and tongues of glacial clay penetrated the lower part. A finely glaciated block of lias limestone occurred here.

1886.—Hughes, Professor T. M'Kenny. On some Perched Blocks and Associated Phenomena.—*Quar. Journ. Geol. Soc.*

The author gives the title of "pedestal boulders" to certain erratics which in the Lake District or its border are seen to stand on a pillar of limestone 18 inches or less raised above the general surface of the Mountain Limestone around. He thinks that such blocks represent "the last push of the great glacier over some of the obstructions that lay in its southward course." He does not think that any estimate of *time* can be calculated from the height of the pedestals.

1886.—Lamplugh, G. W. Glacial Shell-beds in British Columbia. *Quart. Journ. Geol. Soc.*, pp. 276-286.

Numerous shells (14 species) occur in the boulder-clays, many of the shells being perfect, the valves united, &c. Believes, however, that "the whole mass of drift, including the shells, has been pushed up by ice" from the sea-bed into its present position.

1886.—Strahan, A. On the Glaciation of South Lancashire, Cheshire, and the Welsh Border.—*Quart. Journ. Geol. Soc.*, pp. 369-391.

Shows by the striae and rock-fragments that the Liverpool District was glaciated from the N.N.W., but the Welsh Border from W.S.W. The two drifts interosculate along the coast of North Wales.

1886.—Tuckwell, Rev. W. Glacial Erratics of Leicestershire and Warwickshire.—*British Association Report*, p. 627.

Describes the evidence for a south-west stream of boulders of Charnwood Forest rocks extending to Coventry and Stockton. At the latter village a boulder of Mount Sorrel granite (weighing two tons) has been enclosed and inscribed so that its preservation shall be ensured.

1887.—British Association Report: Erratic Blocks Committee.

Manchester Meeting: Fifteenth Report.—Dr. Crosskey points out "a few of the salient facts, established (in the opinion of the writer) by the researches undertaken by the Committee, and which must be fully covered by any theory that may be adopted respecting the Glacial Epoch."

1.—Erratic blocks occur in groups as well as in isolated positions; and these groups have well-defined and distinctive characteristics, and must not be confusedly mixed together. These groups sometimes contain erratic blocks from (only) one locality; sometimes the blocks from various localities are intermixed, but in either case they have characteristics as distinct groups.

2.—The distribution of a considerable proportion of erratic blocks is connected with the existing physical geography of Great Britain, as subjected to elevation and depression during the Glacial Epoch.

The evidence shows that many of them have travelled through the openings between and among our present hills, and that they have been diverted from their courses, or even blocked in their passage, by table-lands and eminences. This fact, it must be noted, is at present stated with respect to a considerable proportion, and not the whole of them.

3.—Erratic blocks have not all been distributed at one and the same time. Their occurrence has been recorded in the reports, in four positions, viz.:—

(*a*) Beneath beds of clay, sand, and gravel.

(*b*) Embedded in beds of clay, sand, or gravel, thickly or sparsely.

(*c*) Resting upon beds of clay, sand, and gravel.

(*d*) Resting upon the native rock of the district.

It is clear that they could not have been deposited at the same time in all these positions.

4.—Erratic blocks occur at various levels above the sea. These levels have been given in the reports.

5.—Streams of erratics have—

(*a*) Crossed each other's paths, so that they have been more or less mixed;

(*b*) Gone over each other under circumstances which have prevented any mixing;

(*c*) Impinged against each other.

6.—Erratic blocks have been distributed—

(*a*) From localities at a considerable distance from their present positions; as, *e.g.*, from Criffel to the Midland Counties;

(*b*) From hills and eminences in their own immediate neighbourhood.

7.—With respect to the admixture of erratic blocks the facts recorded show the following differences:—

(*a*) Local erratic blocks are sometimes intermixed with those from a distance in considerable profusion.

(*b*) Groups of erratic blocks are sometimes found with a very slight admixture of rocks from the immediate locality, and have evidently travelled together as a group.

(*c*) Sometimes groups of erratic blocks contain rocks picked up along the course leading to the mountains from which they are derived; but this is by no means universally the case.

(*d*) In the neighbourhood of various hills purely local groups may be found.

Mr. F. W. Martin reports 41 blocks (Lake-district and Criffel granite, &c.) between Shifnal and Tong; and 54 similar blocks at Codsall, with two at Gunston. All in Staffordshire and Shropshire.

Mr. Westby reports Criffel granite block, 36 × 21 × 19 inches, at Cornmeadow, 2½ miles N. of Worcester.

1887.—Goodchild, J. G. Ice Work in Edenside; and some of the adjoining parts of North-Western England.—*Trans. Cumb. and Westmoreland Assoc.*, pp. 111-167.

Traces a great glacier from Kirkcudbrightshire southwards past Liverpool and Manchester, one branch "spreading out to the east certainly as far as Stafford, where I have found an abundance of recognisable detritus derived from Galloway and West Cumberland." The shells in the boulder-clays, &c., of Lancashire and Cheshire were swept up by a "glacier from the bed of the Irish Sea." It would by no means follow that, when once such organisms had worked their way *into* the ice that the onward movement of the mass would result in crushing the shells. What we know of the behaviour of bodies entombed in modern glaciers would seem to show that substances may

be transported great distances in ice, and in doing so work up from the bottom of the ice to its surface, without being much the worse for their journey (see Tyndall's *Glaciers of the Alps*, p. 76, and J. D. Forbes' *Occasional Papers*, pp. 193-195, upon this point). It is quite likely, too, that the shell-bearing beds may have remained in the ice as frozen masses, and thus would travel much as would solid boulders.

1887.—Hughes, Professor, T. McK. On the Drifts of the Vale of Clwyd and their relation to the Caves and Cave-deposits. *Quart. Journ. Geol. Soc.*, pp. 73-120; with plate.

Describes the gathering ground of the Arenig Glacier, and the passage of a lobe of ice from it northwards up the Valley of the Clwyd. It left behind a blue-grey boulder-clay full of Welsh rocks. Upon, and above, this lower clay we find (at Colwyn Bay, &c.) a reddish shelly boulder-clay which we may call Northern Drift or St. Asaph Drift. Man did not inhabit the Clwydian caves until after the ice had passed away. [The Northern Drift the author assigns to a great submergence.]

In the discussion Dr. Hicks insisted that in the Cae Gwyn and Fynnon Beuno Caves there was the clearest evidence of the presence of man (flint implements) below and sealed-up by glacial drift.

1887.—Martin, F. W. Sections of the Drift between Soho and Perry Barr, near Birmingham.—*Proc. Birm. Phil. Soc.*, pp. 364-371; with plate.

These sections were in the cuttings for a new railway (L. & N. W. R.) from Soho to Perry Barr, crossing Soho Hill and Church Hill in the north-west suburbs of Birmingham. Tough purplish till was seen at the bottom, and 8 feet of reddish sandy clay at the top; between these were contorted clays, sands, and gravels, amounting to from 12 to 20 feet in thickness. Details of 14 erratics (largest—$2\frac{1}{2}$ by $2\frac{1}{2}$ by 2 feet) are given; mostly coal-measure grits, but two were Rowley basalt, and three or four Arenig felsites.

1887.—Prestwich, Professor J. Considerations on the Date, Duration, and Conditions of the Glacial Period, with reference to the Antiquity of Man.—*Quart. Journ. Geol. Soc.*, pp. 393-410.

"I believe that the Glacial Epoch—that is to say, the epoch of extreme cold—may come within the limits of from 15,000 to 25,000 years, and that of the so-called Post-glacial period, or of the melting away of the ice-sheet, to within from 8,000 to 10,000 years."

1887.—Rowe, Rev. A. W. On the Rocks of the Essex Drift.—*Quart. Journ. Geol. Soc.*, pp. 351-363.

The collection was made from the western and north-western parts of

Essex, round the village of Felstead, and from the Great Chalky Boulder-clay and Gravels. No granite was found, and only two small specimens of syenite. Porphyritic rocks—quartz-, tourmaline-, felspar-, are common, with fine-grained dolerites. Flints and sandstones are the most abundant rocks of all, but limestones (many lumps of hard chalk) are also common. The dolerites are remarkably similar to some Scandinavian rocks; and there are granulites, &c., which have come from the same region.

1887.—Woodward, H. B. The Glacial Drifts of Norfolk.—*Proc. Geol. Assoc.*, pp. 111-129.

"The Lower Glacial Clays, which, east of Cromer and near Norwich, consist chiefly of brown stony loam, become westwards so like the Chalky Boulder-clay that no one, from the evidence of pit-sections, could tell one from the other."

The occurrence of palaeolithic implements *beneath* true boulder-clay (as per Mr. Skertchley) Mr. Woodward states to be as yet doubtful and in need of confirmation.

1888.—British Association Report: Erratic Blocks Committee.

Bath Meeting: Sixteenth Report.—Records boulders near Northallerton, York, Norber, &c.; in Essex: near Oldham, &c.

[The "fin-bone of a whale," said to have been found "under about 4 feet of drift" near Leicester, is a recent bone probably brought by some sailor.]

1888.—Crosskey, Rev. H. W. A High-level Boulder-clay in the Midlands.—*British Assoc. Report*, p. 656.

[Title only given in B.A. Report: for the paper itself see *Proc. Birmingham Phil. Soc.* for 1888, pp. 169-181.]

1888.—Crosskey, Rev. H. W. Notes on the Glacial Geology of the Midlands.—*Proc. Birmingham Phil. Soc.*, pp. 169-181.

1.—The High-level Boulder-clay.—Three felsitic boulders lie on the top of Romsley Hill (just south of Frankley Hill) at an elevation of 897 feet.

Prof. Carvill Lewis suggested that these were "outcrops of the Palæozoic floor" in this district, and that the felstones were derived from these outcrops and were not boulders at all. To settle this question, a special examination of the district was made. The railway cutting between the two hills has exposed the Permian beds largely developed in every direction; and a drain section shows Permian breccia near the summit of Frankley Lower Hill. An excavation made in a field near the latter point passed down 10 feet through a compact boulder-clay containing local and Welsh rocks, mostly angular, and all varieties sometimes striated. Professor Lewis at once acknowledged the true glacial origin of the boulders and the clay.

Theories of Transport of the Boulders, &c.—Two theories have been advanced.—(*a*) The boulder-clay, &c., was deposited on these hills by an

enormous glacier coming from North Wales. Such a glacier must have crossed the Severn Valley. (*b*) The Welsh glacier had a more moderate extension, and the boulders were brought on floes and bergs breaking off from the nearest edge of the glacier and dropped upon the Midlands, which were then submerged.

2.—The California Clay Pits.—In pit No. 1 (by the Canal) a bed of boulder-clay (precisely similar to that on Frankley Hill), 9 feet thick, lies on the Bunter Sandstone, and is covered by sands and gravels, 7 feet. The included blocks are angular and striated, they consist of local and Welsh rocks. This section is now obscured.

In pit No. 2 (reached from No. 1 by passing through a tunnel) we have sand at the bottom, overlaid by clay, 42 feet, and then gravel, 8 feet. The so called "Indiarubber" clay in this pit contains only a few rather large boulders, of Welsh and local origin.

In pit No. 3 (on same side of road a little further on) we find 40 feet of the "Indiarubber" clay lying on sands and gravels.

Another pit (No. 4) is close at hand, where Permian rocks are overlaid by 15 feet of clay with glaciated Welsh and local rocks.

1888.—Hicks, Dr. H. On the Cae Gwyn Cave, North Wales; with a note by Mr. C. E. De Rance.—*Quart. Journ. Geol. Soc.*, pp. 561-577.

1888.—Kilroe, J. R. Directions of Ice-flow in the North of Ireland, as determined by the Observations of the Geological Survey. — *Quart. Journ. Geol. Soc.*, pp. 827-833.

"The striae to the *east* of a line drawn from Strangford Lough to Galway Bay all trend in one direction; while *two sets* of striae occur *north-west* of that line, and these generally at right angles to each other." This double set may be accounted for by the Scotch ice (at the maximum period of glaciation) overriding the north of Ireland.

1888.—Martin, F. W. First Report on Distribution of Boulders in South Shropshire and South Staffordshire.—*Proc. Birmingham Phil. Soc.*, pp. 93-118.

The boulders consist mostly of red, grey, and flesh-coloured granites, syenites, felsites, andesites, and various altered ash rocks. No Welsh rocks occur *east* of a line drawn from Lilleshall to Trysull. Where the Bunter pebble beds come to the surface there are few or no boulders.

A long and valuable list of boulders noticed and measured is appended to this paper.

1889.—British Association Report: Erratic Blocks Committee.

Newcastle-on-Tyne Meeting: Seventeenth Report.—Particulars of numerous boulders as furnished by the "Yorkshire Boulder Committee."

1889.—Croll, Dr. Jas. On Prevailing Misconceptions regarding the Evidence which we ought to expect of Former Glacial Periods.—*Quart. Journ. Geol. Soc.*, pp. 220-226.

Dr. Croll's astronomical theory of the cause of the Glacial Period requires the frequent and regular occurrence of glacial conditions during the past stages of the earth's history. But of such conditions we find but scanty evidence in the rocks, and this paper is intended to show how it happens that this is so.

1889.—Martin, F. W. Boulders of the Midland District (with map), being a Second Report.—*Proc. Birmingham Phil. Soc.*, pp. 85-113.

The whole of the ground north of Kingswinford is fairly covered with boulders of English Lake District and Scotch origin; but very few of such occur south of this. There is no distinct line of termination of the deposit, such as a range of hills would form. "The deposit of Lake District and Scotch rocks certainly seems to thin off to the east of a line drawn between Sutton and Lichfield, and south of a line between Enville, Dudley, and Walsall." But much depends on the revealing of boulders by cultivation, &c.; in barren uncultivated districts they are not nearly so easy of detection. "I have found no Welsh boulders north of Stourbridge, or to the south of Stoke, though they extend eastwards as far as Sutton."

"The average percentage of the rocks forming the boulders round Wolverhampton seems to be about 44 per cent. each of Criffel granite and Lake District andesites and felsites; the remaining 12 per cent. being Buttermere syenites, Eskdale granites, Hornblendic granites (probably from the South of Scotland), and local rocks." A long catalogue of boulders mapped and measured is appended to this excellent paper.

1889.—Waller, T. H. Petrology of our Local Pebbles.—*Midland Naturalist*, pp. 174-8, 214-19, 236-42.

1890.—British Association Report: Erratic Blocks Committee.

Leeds Meeting: Eighteenth Report.—So far as the Midlands are concerned, the facts with respect to the erratics appear to establish the following points:—

1.—The boulders have been deposited at distinct periods. At least two of these periods can be well ascertained. In some cases the collection of erratics which have been supposed to show the "intercrossing" of their streams are really the remains of distinct periods of action; not that there has been *no* intercrossing, but that all the supposed cases of it are not accurately described by that term.

2.—There are deposits of boulders in the Midland area which are entirely distinct from each other, boulders from special districts being grouped together.

3.—There are deposits of boulders in which those from different and distant sources are to some extent intermixed; and this intermixture of streams or boulders has to be studied in connection with the physical geography of the country during the Glacial Epoch.

4.—Local hills have formed no effective barrier to some part of the distribution of boulders. In the Midlands, *e.g.*, they are abundant at a level of 648 feet, and not unfrequently lie on the edges of the precipitous side of a hill.

5.—Some streams of boulders, however, have travelled under conditions imposed by the hills and valleys as they now exist.

6.—There are glaciated boulders of local origin intermixed with those not of local origin; but it would seem that where the northern erratics are numerous very few of these are intermixed.

7.—There is also a distinct distribution of boulders from local hills (as, *e.g.*, from Rowley Regis).

8.—There are boulders at almost every level, and, it may be added, beds of boulders are sometimes separated from each other in sections by clays and sands, occasional boulders occurring in the separating clays.

9.—A very considerable proportion of the largest boulders are upon the surface, or just beneath the surface; how far clays and sands may have been washed away from them, however, is a question.

10.—There are notable differences in the shapes of the boulders. Many are angular and subangular; many have their edges much rounded off; others are rough and broken as though just torn from the parent rock. In some collections of boulders there are signs of considerable rolling and wearing as by water; in others signs of ice action are fresh and unworn.

Warwickshire.—Mr. W. Jerome Harrison forwards a note on three boulders in South Warwickshire. In North Warwickshire the watershed which divides the rivers running to the E. and W. coasts of England respectively, forms the boundary line on the east to the remarkable collection of Welsh and Lake District and Scotch rocks described in previous reports as occurring in the Midlands. Of boulder-clays equivalent to those found in the district around Birmingham, Mr. Harrison has found no trace in South Warwickshire. The surface deposits there are mainly a light quartzose gravel, the stones small, with occasional flints. Erratics of any size are rare.

The Two Sherbourn Boulders.—Two and a half miles S. of the town of Warwick lies the village of Sherbourn, close to the right bank of the Avon. At the point where the village street joins the high road is a block of Millstone grit. It measures 29 by 22 by 12 inches. The second Sherbourn boulder lies further up the village street, nearly opposite the school-house. This is a granite block, the felspar of a reddish colour. Its dimensions are 38 by 30 by 21 inches.

The Exhall Boulder.—The village of Exhall is 9 miles S.W. of Sherbourn, and 5 miles due W. of Stratford-on-Avon. The boulder lies by the roadside at the east end of the village. It is a quartzose block, with green specks, possibly vein-quartz. It rests on the Trias near the junction with the

Rhaetic beds. The surface beds of this district appear to be thin gravels, composed of small quartzose pebbles (in which are found *Orthis Budleighensis* and worm-tracks), but with many angular pieces of cherty flint.

1890.—Callaway, C. Quaternary Deposits of Shropshire.—*Midland Naturalist*, pp. 110-114.

J. F. Blake remarks that "north to south ice-scratches occur on Charlton Hill."

1891.—Geikie, Prof. Jas. Presidential Address to Section C.—*Brit. Assoc. Report*, p. 551.

Deals with glacial phenomena in general, most of the illustrations being taken from continental districts.

1890.—Landon, J.—A New Drift Section at Northfield.—*Proc. Birm. Phil. Soc.*, pp. 127-131.

A cutting for a road leading from Northfield Station to King's Norton showed clays and sands containing local, Welsh, and (?) Lake District rocks, with two small and rounded specimens of Criffel granite.

1890.—Wright, G. F. The Ice Age in North America; and its bearings upon the Antiquity of Man. Large 8vo, pp. xviii and 622; with 143 illustrations and four plates. Kegan Paul; 21s.

The glacial phenomena of North America are on a larger and bolder scale than those of the British Isles; and being thus "writ large," they appear to be also simpler and easier to understand. It is certain that the study of this able book must be of the greatest service to every British glaciologist. The author is a leading exponent of the "New School" which admits of but one period of continuous cold and no submergence. The illustrations are largely from photographs which have been very well reproduced.

1891.—Barke, F. Report on Geology.—*North Staff. Nat. Field Club*, p. 19.

There is a continuous sheet of boulder-clay in the Potteries which rises above the 600 feet contour line at Hanley and Tunstall. The included erraties are carboniferous (local) and Lake district in origin. A few chalk-flints occur in the gravels.

1891.—British Association Report: Erratic Blocks Committee.

Cardiff Meeting: Nineteenth Report.—During the past year a N.W. of England Boulder Committee* has been formed. A large number of Lancashire boulders are recorded; also some in Yorkshire, and in the Isle of Man.

* This has since developed into the Glacialists' Association, a meeting of which was held in Birmingham, December 27th and 28th, 1894.—W. J. H.

Mr. F. Barke reports: *Little Madeley.*—Gravel-pit close to 'c' in 'Little' (Madeley) on Ordnance Map, Newcastle-under-Lyme, Staffs. Small boulders of granite not exceeding 12 inches diameter. The gravel-pit is in grass land; its extent not ascertained. Beds of sand and gravel alternate, and contain fragments of shell and chalk-flints. Base of series not exposed. In the vicar's garden at Madeley are two boulders—one "trap," and one granite.

1891.—Bulman, G. W. On the Sands and Gravels intercalated in the Boulder-clay.—*Geol. Mag.*, pp. 337-348; 402-410.

States the case *against* inter-glacial periods forcibly and in detail. "It may be affirmed that the evidence that the intercalated sands and gravels were formed during a mild inter-glacial period is in *no single case* conclusive; that while they are *not* the sort of deposits to be, *a priori*, expected as the result of a mild interval, they *are* just such as would naturally result from the action of subglacial streams, the oscillations in the extent of the ice causing the overlapping of glacial and aqueous deposits, and the work of the ice itself; and that a gradually, but intermittently, advancing ice-sheet, or glacier, could not avoid overwhelming and burying in its own debris masses of vegetation; while the latter, closely following the retreating ice, and growing on its accumulations, could not fail now and again to be buried beneath the deposits of some temporary advance of the same."

1891.—Hicks, Dr. H. On some recently-exposed Sections in the Glacial Deposits at Hendon.—*Quart. Journ. Geol. Soc.*, pp. 575-584; with plate.

The Chalky Boulder-clay (and gravels) of Finchley, &c., extend to Hendon. The materials are largely of local origin, however.

1891.—Hind, W. Pre-glacial Rivercourse at Stoke Road, Shelton. *Report N. Staffs. Nat. Field Club*, p. 53; with two plates of sections.

Current-bedded river-sand, peat, and gravel were covered by boulder-clay 4 to 18 feet in thickness.

1891.—Lamplugh, G. W. On the Drifts of Flamborough Head.—*Quart. Journ. Geol. Soc.*, p. 384; with plate.

No evidence of an inter-glacial period, although three divisions can be recognised in the boulder-clay.

1891.—Kendall, P. F. Hints for the Guidance of Observers of Glacial Geology.—12mo, 55 pp.; price 1s.

An excellent little book. It is issued to all the members of the Glacialists' Association; and may be obtained from the Assistant Secretary, Mr. A. R. Dwerryhouse, 49, Islington, Liverpool.

1891.—Prestwich, Professor J. On the Age, Formation, and successive Drift-stages of the Valley of the Darent; with remarks on the Palaeolithic Implements of the District, and on the origin of its Chalk Escarpment.— *Quart. Journ. Geol. Soc.*, pp. 126-163.

"The author did not suppose that the great northern ice-sheet extended over this area. A southern central ice-area may then have existed in the Wealden highlands, and the ice and snow in these valleys have been local."

In the discussion (Sir) A. Geikie said that "he thought geologists made a great mistake who looked in the Southern Counties for any such traces of ice-action as they were familiar with farther north. There was assuredly no ice-sheet in the south of the island; the Boulder-clay and scratched stones may be entirely absent, nor could he see any satisfactory evidence of floating ice. Yet there could be no doubt that thoroughly glacial conditions did spread over south-eastern England, giving rise, however, to a different class of results from those that attended the more Arctic glaciation farther north."

1892.—British Association Report: Erratic Blocks Committee.

Edinburgh Meeting: Twentieth Report.—This includes the report of the Yorkshire Boulder Committee, and of very numerous boulders in Lancashire by Messrs. S. S. Platt (Rochdale), A. R. Dwerryhouse and J. Lomas (estuary of the Mersey, &c.)

Mr. George Gray reports—"from a gravel pit about 30 feet above the present level of the Severn at Worcester, the following series was obtained, representing all the varieties that could be got:—

Vein Quartz, 1.

Agate, 1.

Buttermere granophyre, 1.

Welsh lavas, 3.

Welsh agglomerate, 1.

Flint, 1.

Eskdale granite (the typical aspect as well as varieties), 9.

Scottish granites (these are all of familiar Galloway types, and include rocks much resembling the varieties found at Creetown and Rigg-o'-Burnfoot), 6.

Rhyolite of the Wrekin, 1.

The Llandovery Limestone (a block about 9 inches long, containing *Stricklandinia*), 1.

The pitchstone of Arran is recorded from the Isle of Man; and the Eurite of Ailsa Craig from the Isle of Man, and from the Vale of Clwyd."

This was the last Report of the long series so ably drawn up by the late Rev. H. W. Crosskey, LL.D., F.G.S. He died at Birmingham, in 1893.

1892.—Brodie, Rev. P. B. Sand-pit at Hillmorton, near Rugby.— *Geol. Mag.*, pp. 321-322.

Pit near "L. and N.W. Railway" shows brown and light-coloured sands, 50 feet thick, false bedded; with flints and liassic fossils. The sand forms a ridge of considerable extent.

Also in *Proc. Warwickshire Field Club*—Proceedings for 1893, p. 37.

1892.—De Rance, C. E. The Glacial Drifts.—*Trans. Manchester Geol. Soc.*, pp. 49-52.

"During part of the past season I have been engaged in surveying the western slopes and valleys of the Pennine Chain to the east of Macclesfield and Congleton, a district of great interest as regards its glacial phenomena. My previous work in Lancashire and Cheshire, extending over more than 1,200 square miles, had given me no opportunity of studying the relations of the drift area to the west with the driftless area to the east; and the district now examined gives, in my opinion, a key to the solution of that problem. In 1869 I wrote an article in the *Geological Magazine* expressing my views on Glacial matters, and subsequently in the Geological Survey Memoir, 'On the Superficial Geology of South-west Lancashire,' published in 1877, I again stated that I considered that *land-ice* had covered the whole of Lancashire up to a certain level, but subsequently the country subsided, and most of the Glacial Drift was deposited under submarine conditions. In so reading the country, I followed the views given to me as authoritative when I first visited the country in 1868. Recently my duties have led me to areas where not only these Glacial Drifts thinned off, but where they are entirely absent, and I have had the opportunity of carefully studying the relations of the drift at these high elevations, and the good fortune to discuss the conditions there obtaining with the Rev. Professor Wright, of Oberlin College, U.S., at Cardiff, and subsequently on the ground, just before his return to America, which resulted in my making up my mind to neither write, nor speak, as regards any definite views on the Glacial Drift question, until I had further studied the question with the new lights, on the ground on which I was engaged, for, as regards previous observations, I can endorse a remark I heard made by an eminent Q.C. before a Parliamentary Committee—'that the eye only sees what the brain looks for!' Since Dr. Wright's visit to Macclesfield, in August of last year, I have continuously pondered over and studied these matters, with an entirely open mind, and now, I admit with very great reluctance, I feel it my duty to tell you, that though the late Professor Carvill Lewis may have been in extreme in some of the views he held, as regards his application of the results of his studies, in the United States, to the phenomena observable in Britain, I believe, in the main, he was right, and I feel profound regret that I did not realise it when he addressed the British Association at Birmingham, and I must confess that I did not see the force and weight of the evidence he adduced until I read and carefully studied Dr. Wright's 'Ice Age in America,' since which my eyes have been opened, and I realise the true significance of finding fragments of sea shells up to 1,280 feet, and granites from the S.W. of Scotland, and 7 feet boulders of andesites from the Lake District at 1,330 feet. Much light is thrown on

the glacial question by careful study of the new one-inch Ordnance Map, in which the 1,250 feet contour is engraved (which, curiously enough, is omitted on the six-inch map), and which is of great importance as regards glacial matters. Westward of the Pennine axis, the Glacial Drift rises to this level, or somewhat above it, in both Lancashire and Cheshire; eastward, though lower elevations may occur, the drift is conspicuous by its absence. Gravel and sand mounds constantly occur, with shell fragments, but perfect shells are rare, and the two valves of bivalves united are invariably absent, and when fragments of shells can be identified, they are found to belong to species which indicate that they did not all live in water of the same depth, all of which is very much against the idea of their being deposited in the sea or thrown upon a beach. More than that, some of them are indicative of a warmer climate than at present obtains. Apparently they have been caught up on the sea-bottom from deposits of various ages, and forced inland and deposited at various elevations. Apart from this, you have the remarkable fact that a few miles east of where these high level drifts occur, in the Buxton district, you have an extensive area below the 1,250 feet contour where not a trace is found of any glaciation, and not a fragment of Buttermere granite, though thousands of tons of Buttermere granite are spread over Cheshire. Again, in some of these upland valleys, 600 or 700 feet in depth, you get the drift on one side but not on the other; and the only explanation of this, appears to me, is that the deposits could not have been left by water. If water had deposited these drifts they would have filled up the valleys."

1892.—Holmes, T. V. The New Railway from Grays Thurrock to Romford: Sections between Upminster and Romford.—*Quart. Journ. Geol. Soc.*, pp. 365-372.

Elevation 100 feet above sea-level; 10 to 15 feet of Great Chalky Boulder-clay are covered by 10 to 12 feet of sand and gravel. This is one of the most southerly exposures of the Great Chalky Boulder-clay; and its low elevation would seem to show that the Thames Valley is, in part at least, pre-glacial.

1892.—Kendall, P. F. Glacial Geology, Old and New.—*Geol. Mag.*, pp. 491-500.

Any explanation of the phenomena of the Ice Age must state:—

1.—The sequence of events in Britain during Glacial times.

2.—The limits of the submerged areas [if any].

3.—The sources of the glaciers which gave origin to the icebergs carrying, *e. g.*, the Criffel granite to Moel Tryfaen.

4.—The mode of origin of Boulder-clay, especially of the intensely hard Till utterly devoid of stratification which is sometimes met with.

5.—The mode of production of the striae found so commonly on the rock-surfaces.

6.—The mode of origin of the "ground-moraine."

7.—The distribution of life in any suppositious glacial sea.

It may be remarked that all these points are easy of explanation to those who (with Mr. Kendall) consider the Glacial Period as "one and indivisible," and as the product in the main of a great sheet of land-ice, while they are full of stumbling-blocks to the advocates of the "submergence with icebergs" theory (as Mr. Mellard Reade).

Mr. Kendall then proceeds to point out that of rocks foreign to the district (of Lancashire and Cheshire) there is a great preponderance of Lake district rocks on the eastern side of the area, and of Scottish rocks on the western side.

The *local* stones are found—practically without exception on the S. and S.E. sides of their native rocks; a fact which points to their transport by a sheet of land-ice advancing from the N. and N.W. Mr. Kendal adds—"The facts given above may, I think, be best explained by supposing that a great lobe of ice came in from the Irish Sea, pushed over the low grounds of Lancashire, Cheshire, and Shropshire, and had its final melting place in the neighbourhood of Bridgnorth and Wolverhampton, where an amazing profusion of northern rocks—'the overshot load' of Mackintosh—and great piles of gravel and sand mark its termination. Upon its left flank, in the upper part of its course it was confluent with ice coming from the Lake district, and along the line of composition the thin trail of Shap granite [extending 'from the angle of Morecambe Bay in a curved line round *via* Longridge to Whalley'] is scattered. To the southward of Bacup it followed a line sub-parallel with the Pennine axis, which, however, it never crossed. On the right flank it rested against the outer line of hills of the great Welsh cluster, Halkin Mountain, Hope Mountain, Frondeg, and Gloppa."

As to marine shells in the Drift, Mr. Kendall remarks that the sections from which such shells have been recorded all "lie directly in the course of ice which, by all the physical indications such as striae, transport of boulders, and the like, can be shown to have come in upon the land from seaward." These shells have been scraped off the sea-floor by advancing glaciers, for we find (1) that they always occur *along with* stones foreign to the district; (2) the shells are comminuted and pounded in such a fashion that one may work for hours even in some of the most prolific beds and not find a perfect shell of any sort; (3) the shells are *not* accompanied by the bored and encrusted stones which we find on real beaches and shallow sea-bottoms; (4) the contents of the shells are usually different to that of the matrix in which they are now found, thus the shells in the boulder-clays are often full of fine sand; (5) the shells form a *mixed* fauna the individual species of which could not have lived together, and *there is an absence of deep-water forms.*

1892.—Marshall, W. P. On the Ice Ages, Past and Future, and their Causes.—*Midland Naturalist*, pp. 121-131; with one plate.

An exposition mainly of Dr. Croll's Astronomical Theory of Glacial Epochs

1892.—Monckton, H. W. On the Gravels south of the Thames from Guildford to Newbury.—*Quart. Journ. Geol. Soc.*, pp. 29-47.

"The theory which I have adopted is that all the gravels in the area here dealt with were formed after it had for the last time risen above the sea. As soon as denudation began valleys were formed and gravels spread out in them. By degrees the sides of the valleys were destroyed, the gravel came to protect the ground on which it lay, and so stood out as a hill. Then the gravel itself was attacked and carried down by degrees to lower levels, where it was again spread out and again protected the ground on which it lay, becoming a terrace, a spur, or a minor plateau, and thus the process has been repeated even to the present day.

"I also believe that the Glacial [= Northern] Gravels in the area dealt with never extended more than a mile or two south of Reading, and that none of the gravels in that area are of marine origin."

The gravels described are largely formed of flint pebbles, and of sand and sandstone from the Bagshot Beds.

1892.—Nicholson, A. C. On High-level Glacial Gravels at Gloppa. *Quart. Journ. Geol. Soc.*, pp. 86-95.

Gloppa is two miles N.E. of Oswestry. Here a ridge of gravel and sand about 1000 yards long rests on the Millstone Grit, and has been largely worked to supply sand for filter-beds. Numerous Scotch, Lake District, and Carboniferous boulders occur.

The recent shells found included 11 Arctic species; 11 British and Arctic; 2 southern forms; and 57 which still inhabit the seas round our coasts. This fauna (according to Mr. C. Reid) agrees fairly with that of Moel Tryfaen.

1892.—Prestwich, Professor J. On the Raised Beaches, and "Head" or Rubble-drift of the South of England.—*Quart. Journ. Geol. Soc.*, pp. 263-343; with plates.

Notes the occurrence of rubble-drift or "head" on the slopes of the Cotteswolds (p. 314), and on the slopes of the Malvern Hills where it contains mammalian remains. The materials are always angular and of local origin.

1892.—Reade, T. M. Glacial Geology: Old and New.—*Geol. Mag.*, pp. 310-321.

States that his study of the Drift during a period of twenty years has led him to the conclusion "that the whole of the drift deposits were one glacial series from top to bottom." Mechanical analyses of twenty samples of Till have all yielded rounded and polished quartz grains; and these aid in proving that the Drift was laid down in an icy sea during a period of submergence.

1892.—Reid, C. On the Pleistocene Deposits of the Sussex Coast. *Quart. Journ. Geol. Soc.*, pp. 344-364.

At Selsey Bill and Wittering large striated erratic blocks occurred, of which those that could be identified have travelled from the westward. Above them comes clay with Pleistocene marine molluscs evidencing a mild climate: higher still are the raised beach and Coombe Rock [="Head" of Professor Prestwich]. This last-named resulted—the author thinks—from the following conditions:—"The erosion of the valleys, and the deposition of the eroded material in the form of widespread sheets of angular chalky detritus, resulted from the fall of summer rain on a shattered surface of Chalk, rendered impervious by freezing during a winter of Arctic severity." He thus thinks that at Selsey we have evidence of "an inter-glacial period."

1892.—Wright, G. F. Man and the Glacial Period (with Notes on British Glacial Geology by P. F. Kendall).—Kegan Paul, London. 8vo, pp. 385; illustrated; 5/-

This book embodies the work of the most recent and advanced students of Glaciology, and is perhaps the best introduction to the whole subject which has been published. Existing glaciers are first described; and the knowledge so obtained is used to explain the signs of past glaciation. The author considers "the whole Glacial Epoch as constituting a grand unity with minor episodes;" that is, he does not believe in Geikie's "inter-glacial" epochs. The *causes* of the cold are considered to have been mainly an elevation of the great northern continental masses, combined with a depression of Central America by which the Gulf-stream was permitted to flow into the Pacific. As regards *time*, the author thinks that the whole Glacial Period was probably comprised in less than 100,000 years; and that it ended—in North America at all events—from 7,000 to 10,000 years back.

1892.—Wright, G. F. Supposed Inter-glacial Shell Beds in Shropshire. — *Bulletin Geol. Soc. America*, vol. III, pp. 505-508.

At Ketley, near Wellington, marine shells occur under true Till, and with a thick bed of sand beneath. Height above sea-level is 500 feet.

1893.—British Association Report: Erratic Blocks Committee.

Nottingham Meeting: Twenty-first Report (drawn up by Mr. P. F. Kendall, Chapel Allerton, Leeds, Secretary).

"The Committee regret that they have been obliged to publish merely a digest of their very voluminous report, but arrangements are in progress whereby a type-written copy of the detailed report will be lodged in public libraries in London, Edinburgh, and Dublin."

Mr. De Rance reports on the Macclesfield district; Miss L. J. Shipton and Captain Dwerryhouse record 1,176 boulders from the east side of the Dee

Estuary; and there are other records from Flintshire, Lancashire, Isle of Man, and Yorkshire.

Staffordshire.—Mr. W. Hampton, a boulder of Lake District Andesite at the Mousecroft Brickworks (450 feet above sea-level), Hanley.

Mr. F. Barke reports from "between New Park and County Cricket Ground, Hanley: In an upper bed of boulder-clay—2 Buttermere granophyres, 2 Lake District Andesites, 1 Scottish Granite, 1 Millstone Grit."

Small boulders, chiefly from a lower bed of red boulder-clay: 10 Buttermere granophyres, 6 Lake District Andesites, 1 Lake District Andesitic Agglomerate, 4 Eskdale Granites, 1 Scottish (?) Granite, 8 Millstone Grits, 1 Bunter Pebble.

1893.—Browne, M. Geology of the Borough of Leicester.—*Trans. Leicester Lit. and Phil. Soc.*, vol. III, pp. 123-240; plates i-v.

The Rhaetic shales show glacial striae at one point. Abstracts of papers, and details of numerous sections are given.

1893.—Deeley, R. M. The Glacial Succession.—*Geol. Mag.*, pp. 31-35.

Compares Professor Jas. Geikie's theories (as stated in a paper read to the Royal Society of Edinburgh in May, 1893) with his own arguments (*Quart. Journ. Geol. Soc.*) Gives comparative table.

1893.—Reade, T. M. The Drift Beds of the Moel Tryfaen area of the North Wales Coast.—*Proc. Liverpool Geol. Soc.*, vol. VIII, pp. 36-79; plates i-viii.

Records a pebble of Shap granite from the Alexandra quarry on Moel Tryfaen. Argues in favour of the submergence theory.

1893.—Geikie, Jas. Fragments of Earth Lore.—Large 8vo, pp. 428; six plates. Bartholomew, Edinburgh.

This fine volume includes fourteen chapters which are reprints of articles that appeared in various magazines at various times, and which are here collected and re-published. They nearly all deal with glacial subjects. Among the most important are:—Chap. V. The Long Island, or Outer Hebrides. Chap. VI. The Intercrossing of Erratics in Glacial Deposits. Chap. VIII. Recent Researches in the Glacial Geology of the Continent. Chap. IX. The Glacial Period and the Earth Movement Hypothesis. Chap. X. The Glacial Succession in Europe. Chap. XII. The Evolution of Climate. Chap. XIII. The Scientific Results of Dr. Nansen's Expedition.

The style is transparently clear and interesting; and whether we agree with Professor Geikie's theories or not, we must allow that he marshals his facts most ably.

1893.—Gilbert, C. J. Geology of Sutton Coldfield.—(Read before the Vesey Club. Privately printed.)

1893.—The Glacialists' Magazine: monthly, price sixpence (altered to a quarterly, price 1s. 6d., in 1895).

This admirable periodical is edited by Mr. P. F. Kendall (Lecturer on Geology at the Yorkshire College, Leeds), assisted by Messrs. Warren Upham, C. E. De Rance, and J. Lomas. It is the organ of the Glacialists' Association, and dates from August, 1893. The London Agent is Mr. F. H. Butler, 158, Brompton Road, S.W.

1893.—Harker, A. Scandinavian Rocks in the English Boulder-clays.—*Geol. Mag.*, p. 140.

Gives list of several varieties of gneiss rocks occurring in the boulder-clays of Holderness, which he has identified as of Norwegian origin.

1893.—King, W.W. The Clent Hills Breccia.—*Midland Naturalist*, pp. 25-37.

All the fragments are angular; but those which show striae are extremely rare. The breccia is of Permian age, and is probably derived from a buried ridge of Palaeozoic rocks lying close at hand. It is not probable that ice brought the stones from a distance.

1893.—Lomas, J.—On the Glacial Distribution of the Riebeckite-Eurite of Ailsa Craig.—*Brit. Assoc. Report*, pp. 707-708.

The rock is a granophyre or eurite, and contains the rare blue variety of soda-hornblende, *riebeckite*. It has been found as a boulder in glacial deposits by Mr. P. F. Kendall and by the author in the Isle of Man and at Moel-y-Tryfaen; by the author in Anglesey; at Liverpool, Garston, and Hale Head in Lancashire, and at Dawpool and Birkenhead in Cheshire. The Rev. Mr. Barker has recorded it from the Vale of Clwyd. It is always accompanied by South Scottish granites, and where these predominate, as in the Isle of Man, it is common. About Liverpool the Scotch rocks are about in the same proportion as those of Lake District origin, and further east the Scotch cease altogether.

Floating ice could not have transported the Ailsa Craig and other northern rocks, as there is not a free intermingling of types. There is also a vertical uplift of over 200 feet from Ailsa Craig (1,140 feet) to Moel-y-Tryfaen (1,350 feet). The ridge, of which Moel-y-Tryfaen forms a part, acted as a barrier, and destroyed the force of the Snowdonian ice northwards, and thus the northern ice got the mastery and pushed the northern erratics up to the summit of Moel-y-Tryfaen.

1893.—Madsen, Herr Victor. On Scandinavian Boulders at Cromer. *Quart. Journ. Geol. Soc.*, pp. 114-116.

Noted three boulders [or pebbles, rather. W. J. H.] at Cromer, two of which were porphyries from Dalarne, in Sweden, and one from Christiania.

In the discussion "Dr. Hicks said that when Dr. Torell visited Finchley with him some years ago, several boulders obtained from the Drift there, were recognised by Dr. Torell as being identical with Scandinavian rocks." Mr. J. W. Davis said that Mr. A. Harker had identified rocks from the boulder-clay of the East Riding of Yorkshire as being of Scandinavian origin (See *Proc. Yorkshire Geol. Soc.*)

1893.—Monckton, H. W. On the Occurrence of Boulders and Pebbles from the Glacial Drift in Gravels South of the Thames.—*Quart. Journ. Geol. Soc.*, pp. 308-319.

The southern limit of distribution of the Northern Drift materials in hill- and valley-gravels very nearly coincides with the river Thames, at least in the country east of Pangbourne, but not absolutely so, and the object of the present paper is to show where and to what extent the Glacial Gravels or their debris are now to be found south of that river. None of the "boulders" appear to attain to the dimensions of a cubic foot. Red and brown quartzite pebbles seem to have travelled the best.

1893.—Reade, T. M. Eskdale Drift and its bearing on Glacial Geology.—*Geol Mag.*, pp. 9-20.

The Eskdale granite occurs "in almost every section of drift" from St. Bees to the south of Shropshire, and from Macclesfield to Nevin. It is coarse-grained, and contains much light pink felspar. Thinks that the *divergence* of the paths of the boulders proves that they must have been carried by *floating ice.*

1893.—Reade, T. M. Glacial Geology, Old and New.—*Geol. Mag.*, pp. 35-37.

A reply to Mr. Kendall's paper of November, 1892. Thinks that the crossing of the lines of travel of the boulders, and the way in which they are "inextricably intermingled," are dead against the land-ice theory.

1893.—Russell, Israel C. Second Expedition to Mount Saint Elias.—*Thirteenth Report U. S. Geol. Survey*, pp. 1-91; illustrated.

This contains a description of the Malaspina Glacier, whose length is 70 miles with a breadth of 20 to 25 miles. The fringing moraines are often covered by trees, and "in many places the ice beneath the dense forest is not less than a thousand feet thick." Many of the features described help greatly in understanding the glacial phenomena of the British Isles.

1893.—Woodward, H. B.; Reid, C.; and Blake, J. H. Record of Excursion to Norwich, the Bure Valley, Cromer, and Lowestoft.—*Proc. Geol. Assoc.*, pp. 54-69; illustrated.

A valuable account of a region which is classical to all glacialists.

1893.—Cumming, L. The Geology of Rugby.—*Report Rugby School Nat. Hist. Soc.* for 1892; pp. 4-8.

1893.—Wallace, A. R. The Ice Age and its Work.—*Fortnightly Review*, vol. LIV, pp. 616-633, and 750-774.

PART I.—Erratic Blocks and Ice Sheets.
PART II.—The Erosion of Lake Basins.
The author is a firm believer in the erosive power of ice.

1893.—Reade, T. M. High-level Shelly Sands and Gravels.—*Natural Science*, vol. III, pp. 423-435.

Believes that these deposits mark a period of great submergence during the Glacial Epoch.

1893.—Anon. Record of New Boulders.—*Caradoc Record of Bare Facts in 1892;* p. 24.

Notes Eskdale granite ½ mile east of Church Stretton and at All Stretton; grey granite at All Stretton; grey slate ¾ mile E.S.E. of Smethcote; basalt ½ mile east of Lydham Heath Station, and also 3 miles N.W. of Oswestry.

1893.—Kendall, P. F. Supposed Erratics on the Cotteswolds.—*Glacialists' Magazine*, vol. I, pp. 97-99.

Thinks that the beds on Cleeve Cloud described by Mr. Lucy are really not drift at all, but weathered Jurassic rocks *in situ*.

1893.—Lucy, W. C. Presidential Address.—*Proc. Cotteswold Nat. F.C.*, vol. XI, pp. 6-13.

Describes clays and sands on Cleeve Cloud at a height above 750 feet, which he considers to "belong to the period of the great submergence" in the Glacial Epoch.

1893.—Howorth, Sir H. H. The Glacial Nightmare and the Flood.

Valuable as a history of the subject of Glaciology, little as we may agree with the author's conclusions.

1894.—British Association Committee appointed to report on—"The Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other localities." Report of the Committee, consisting of Mr. J. Horne (chairman), D. Robertson, T. F. Jamieson, J. Fraser, P. F. Kendall, and Dugald Bell (secretary).

"Selecting the shelly clay at Clava as a typical example of the Scottish high-level shell beds, the Committee have meanwhile confined their operations to this locality." The Clava deposit occurs on the east side of the Nairn Valley, 6 miles due east of Inverness. It is 200 feet above the river, and 500 feet above sea-level. Excavations were made, and showed the following section in the "Main Pit":—Surface soil and boulder-clay, 43 feet to top of ridge of Drift, but only the lower 12 feet of this is exposed in the section; fine sand, 20 feet; blue shelly clay, 16 feet; coarse yellowish-brown gravel, 10 feet.

It was not safe to dig this pit deeper, so several bore-holes were put down, which showed 21½ feet of "brown clay," with stones, to occur underneath the lowest deposit in the "Main Pit," while beneath all came the solid rock—Old Red Sandstone Grits. The shelly clays appear to be continuous for a distance of 190 yards, as traced by the line of borings. The striae seen in the neighbourhood, and the transport of boulders, point to a motion of ice from the S. and S.W. towards the N. and N.E. The "shelly clay" has yielded about 24 species of molluscs, chiefly littoral and Arctic forms.

The majority of the Committee think that these shells lived and died where they are now found, and that it indicates a submergence of the land to the extent of over 500 feet. Messrs. Bell and Kendall, however, do not admit this, and remark—"On the whole, our opinion, with all deference, is that we have not reached a solution of the difficulties connected with the Clava deposits."

1894.—Kendall, P. F. Glacial Geology of the Isle of Man.—*Journal of the Isle of Man Nat. Hist. and Antiq. Soc.*: 44 pp., with plate, map, and sections.

An admirable and instructive paper. The Isle of Man was glaciated by moving land ice, which overtopped its highest mountain (Snaefell, 2,034 feet). The ice moved from north-east to south-west. There is no evidence of marine action except certain raised beaches, which indicate a post-glacial elevation of about 20 feet. The erratics in the low-level boulder-clays include many granites from the south of Scotland, and a few Lake District rocks. Pebbles of Eurite from Ailsa Craig are not uncommon. In the high-level deposits only local stones occur. The reason assigned is that the lower layers of ice were divided by and flowed round the precipitous north end of the Island, and that the upper ice (by which alone the mountains were overridden) was "clean" or free from detritus. The low-level drifts of the north of the Island have yielded 81 species and varieties of shells, all of which the author believes to have been pushed up by the ice from the bed of the North Sea.

1894.—Cameron, A. C. G. Note on a Large Mass of Chalk at Catworth, in Huntingdonshire.—*Geol. Mag.*

This is a "boulder" of such size that a large village is actually built upon it. The great Chalky Boulder-clay in this county contains an immense

amount of chalk. The nearest outcrop of the Chalk Formation is 25 miles east. Some of the boulders at Catworth appear to be Scandinavian rocks.

1894.—Geikie, Jas. The Great Ice Age and its Relation to the Antiquity of Man.—Third edition, large 8vo, pp. xxviii and 850; 78 woodcuts; 18 maps and charts.

This classical work is a great storehouse of facts; and is most decidedly a work which no glacialist can afford to be without. The author believes in Croll's Theory of climatical change being due to variation in the form of the earth's orbit.

The book includes two valuable chapters by Professor T. C. Chamberlin on the Glacial Phenomena of North America.

1894.—Lewis, Professor Carvill. Glacial Geology of Great Britain and Ireland, edited by Dr. Crosskey (with an appendix by P. F. Kendall).—Large 8vo, pp. lxxx and 469; with maps, &c. Longmans and Co.; 21s.

The introduction to this volume (pp. xvii-lxxii) has been admirably written by Dr. Crosskey, aided by some valuable notes by Mrs. Lewis. This lady writes (p. xxxiv)—"Having seen that the main ice-sheet of Ireland was composed of streams issuing from five distinct local centres, while the glaciers from the Reeks and the Dingle Mountains evidently never united with each other or with those from the north or the east, Professor Lewis was prepared to find a corresponding series of phenomena in England. His subsequent observations proved this idea to be well founded, and having carefully examined all but one of the areas reported as showing the unmistakable action of land-ice, his opinions underwent few changes worth noting until he came to the last of these localities, the patch of drift on the summit of Frankley Hill, which was critically examined in the presence of the Rev. Dr. H. W. Crosskey.

"The study of a new cutting in the deposits at California, made a few days later, in company with the same authority, confirmed the impression gained at Frankley Hill, and it was his intention to re-survey all the drift-covered areas of England lest a similar deposit elsewhere might possibly have escaped his notice. From the nature of the drift on Frankley Hill, and from the direction of the trail of scattered boulders of Arenig rock lying between that point and the Welsh frontier, Professor Lewis felt convinced that here were the genuine traces of '*a very ancient glacier*,' between which, and the phenomena he had just been studying, as vast an interval of time had elapsed as between those of the great Glacial Epoch and the present day."

Professor Lewis came to the British Isles in 1885, hoping to trace here the same "terminal moraines" in connection with which he had been doing such good work in the United States. He believed in *one* Glacial Epoch only, until—only a few months before his death—he visited the "high-level boulder-clay" in South Staffordshire in company with Dr. Crosskey. Professor Lewis's notes of this visit are as follows:—

"At Rubery I leave the train and go to the top of Frankley Hill, and on the ridge in Frankley Farm I get two men to sink a well 10 feet deep. In the field are many fragments of Silurian shale, sometimes fossiliferous, also vein-quartz, and angular fragments of Arenig felsite. Huge blocks of this felsite lie at the side and base of the hill, near the railway. None of these are glaciated, and not one is rounded.

"The pit on Frankley Hill being sunk from 10 to 11 feet, and water coming in, I stop work. We have passed through a genuine till. I made a full collection of specimens, nearly all of which were angular, and many of them were well glaciated and scratched. I took some finely glaciated stones out myself. Silurian shale (sometimes with trilobites) is commonest; a finely glaciated piece of coal, 6 inches long, was found. At 6 feet deep is a boulder of Arenig felsite, $1\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot, angular, but smoothed on one side. This is a highly interesting deposit. It is the till of an ancient glacier clearly full of angular fragments. *Is it not the glacier of the first Glacial Epoch?*"

At Romsley Hill the boulder-clay was absent. Although the extraordinary character of the breccia of this hill—composed as it is of angular fragments—gives it, at first sight, an *appearance* of being glacial. Professor Lewis, as soon as it was examined, had not the slightest hesitation in recognising the fact that, whatever its origin, it is Permian, and not "till" of the Glacial Epoch.

He writes: "I go to the top of Romsley Hill. On the very summit is a well 100 feet deep, going through Permian breccia. A digging at its top gives an exposure of this remarkable breccia. It is made mainly of angular fragments of volcanic rocks of various kinds, felsites, ashes, &c. It is called held to be of *glacial origin* by Sir Andrew Ramsay.
locally 'Rotch' 'or 'Roch.' This is the celebrated Permian conglomerate

"I had a hole dug 10 feet deep in the 'Rotch.' Many angular fragments were taken out, of felsites, porphyries, tuffs, &c. I found no Arenig boulders. This is Permian breccia. On top of the hill are four large boulders, three of Arenig felsite, and one said to have been taken out of the 'Rotch' slightly beneath the surface. *These boulders came from Wales in the first glacial epoch, since which time great erosion has occurred.*"

Dr. Crosskey adds—"The peculiar striation and character of these boulder-clays and erratics indeed rendered it inevitable that Professor Lewis, holding the general views he did, should come to the conclusion that they must be referred to a different epoch from that to which the extra-morainic lakes and great terminal moraines which he had described belonged."

The configuration of the country, and the levels of its plains and undulations of ground, entirely exclude the theory that any extra-morainic lake could have been formed of sufficient depth to have floated boulder-laden bergs, and even carried masses of true glacial "till" to the summits of the Frankley and Romsley Hills. Such a lake would require to have been more than 900 feet deep; and no boundaries capable of confining such a mass of water either now exist, or can be imagined to have existed during the glacial period. These hills also stand twenty miles to the south-east of Professor Lewis' great

terminal moraine; and no glacier so vast as to sweep over them could have had its course marked by those particular deposits to which Professor Lewis gives that name; or would be confined within an area in the slightest degree corresponding with the glaciated region indicated by them. I do not doubt that Professor Lewis would have more than questioned whether the high-level glacial deposits under discussion prove *submergence.* Indeed, I gathered from him in conversation that he attributed them, together with any corresponding deposits that further investigation might show should be classed with them, to the upward push of a great glacier of the first epoch. The distinction between the two epochs, however, is the point now being considered.

Another series of sections, although at a lower level, had a strong influence in bringing Professor Lewis back to a belief in two epochs.

I accompanied him to some clay-pits at California, a village about four miles south-west of Birmingham, and in the direction of Frankley Hill, and what he saw there confirmed him in the opinion that in England he had been chiefly working among the remains of their existence left by the glaciers, morainic lakes, rivers, and torrents of the later glacial period.

The height of the California clay-beds is about 520 feet above sea-level; and at their base, resting on the Bunter sandstone, is a true till containing Welsh erratics, intermixed with glaciated blocks of local origin. Here again, as we studied the general aspect of the country, Professor Lewis said that no lake could have stood at the level of the sections.

He also pronounced the California till to be identical with that on Frankley Hill. In his manuscript notes he writes as follows:—"California (October 28, 1887). Admirable and fresh section. Here and now for the first time I see the *lower till*, full of angular pieces of sandstone, shale, Permian rock, and occasionally Arenig felsites. They are rarely striated; none are rounded; and all are unusually angular as in a breccia. It is identical with that I saw on Frankley Hill: red colour, compact, *unlike recent glacial till;* like old Scotch till, according to Dr. Crosskey.

On this is a sand of yellow colour; made mainly of quartz with shales, silurian, &c.

In the second pit this sand is seen plainly overlaid by a quite thick deposit of Indiarubber-like clay, almost free from pebbles, and fully 25 feet thick. In the upper part of this clay an erratic occasionally occurs.

The clay is laminated very indistinctly. On this is the wash of quartzose gravel, and brick-clays with boulders, being probably the same as the flinty gravel of the Midlands and the "Northern Drift" of South England.

There is a fine exposure in the third pit.

The lower till is, if not made by a glacier, made by water close to the end of a glacier, perhaps when it was at Frankley Hill.

Before he had seen the lower till Professor Lewis wrote of the beds (above this till)—"There seems to me but one clay and gravel, both of the same age, and due to freshwater torrents issuing from the melting ice"; and respecting the gravel of the (surface) bed he especially remarks—"This is clearly a torrential gravel resembling the Philadelphia red gravel."

Professor Lewis records the following section at the three adjacent clay pits at California:—"*Bed 1*, Surface brick-clay and yellow gravel, 4 feet; *Bed 2*, Tough red (Indiarubber) clay, in upper part occasional stones; Permian blocks being striated; some Welsh erratics, in lower part generally free from stones; tenacious, 25 feet. *Bed 3*, Yellow false-bedded sand, often fine; Quartzose sand, 15 feet. *Bed 4*, Tough till with striated Welsh rocks, felsites, and shales, &c., 6 feet. Below which comes the Bunter sandstone."

In a manuscript note on "the origin of the so-called glacial drift about Birmingham," Professor Lewis indeed maintains with regard to this "drift" generally, that it is "the product of large rivers which at the time of the melting of the great glacier* flowed across the country. The glacier extended no farther south than Madeley, some thirty miles north of Birmingham, and its terminal moraine is finely shown in the cuttings of the L. & N. W. Railway. Great rivers issued from the ice at that point and ran southward, and one of them passed Birmingham. . . . The contorted gravel sections described by Mr. Martin are due to torrents and a frozen soil."

The "high-level" deposits with marine shells at Moel Tryfaen, &c., Professor Lewis believed had been pushed or thrust up by a glacier from the sea-bed to their present positions.

Of the sandy beds near Wellington Professor Lewis writes:—"I examined some brickyards and sandpits near Wellington, and on the N.W. side of the Wrekin. In a brick-pit I saw an exposure of five feet of brick-clay, containing many angular fragments of local rock with pebbles and erratics from the Lake District, Scotland, and Wales. I made a collection of boulders here; which include Wrekin red granulite, flints, striated Silurian shale pebbles, Lake District felsites and granites, &c. In another pit I saw a red sand resembling that of Lilleshall, but here devoid of shells. There seems to be no genuine moraine heaped against the Wrekin, as I at first thought. With Dr. Callaway I visited some sandpits in Watbury Street, one mile east of Wellington. The drift forms a continuous ridge from Wellington. There are two pits, both freshly exposed, one on the north, the other on the south side of the road. On the north side we saw at the bottom a shell-bearing sand clearly marine, full of fragments of shells, often quite sharp and thin, and occasional whole ones; being a red sand without marked false bedding. On this is sand ten feet thick, and more free from shells. Over this is a tough loamy clay, stratified, perhaps the indiarubber clay of California, being free from shells. Erratics appear at the top of this clay, which is a genuine boulder-clay in which Criffel granites and other erratics, often well striated, occur, forming the top of the section. Across the road is quite a different succession, the pit being at a somewhat higher level. No shell-bearing sand occurs here, but we have some thirty feet of red sand alternating with bands of clay. Clay is seen at the bottom of the pit, then sand, and then occasional layers of sandy clay in the sand.

The upper part of the sand, which is not false-bedded, but is horizontally

* Doubtless the reference is to Professor Lewis' great glacier of the second epoch; the *lower till* was the only deposit in the district he assigned to the first epoch.

laminated, shows a succession of ripple-marked horizontal layers which project by weathering. These ripple-marks have been described by T. M. Reade (*Q. J. G. S.* for 1884, p. 207) and Mark Stirrup (*Proc. Manch. Geol. Soc.*). On top of the whole is a clay full of erratics; a true boulder-clay or till, five feet deep, of gray colour, being a brick-clay such as that I examined on the other side of Wellington, near the Wrekin; and the same as that on top of the section on the north side of the road.

I cannot say that this clay was made under a glacier. It lies quietly on the older sands, *as if made in the same body of water.*

In the pit on the north side, at one end the clay and the sand are curiously intermixed and drawn out into tongues and bent over. This is not due to a glacier, but to *creep* down the side of a hill, as can readily be proved here. The great interest in these two sections lies in the fact that there *are no unconformities, but passages of each deposit into the next, indicating a continuous submergence under varying conditions.*"

The papers by Professor Lewis reprinted in this book are five in number:

1.—*Comparative Studies upon the Glaciation of North America, Great Britain, and Ireland.* Read at the Meeting of the British Association in Birmingham, in 1886.

2.—*The Terminal Moraines of the Great Glaciers of England.* Read at the Manchester Meeting of the British Association in 1887.

3.—*On some important Extra-morainic Lakes in Central England, North America, and elsewhere, during the Period of Maximum Glaciation, and on the Origin of Extra-morainic Boulder-clay.* Read at the Manchester Meeting of the British Association in 1887.

4.—*The Supposed Threefold Division of the Drift.* [MSS. found among Professor Lewis's papers.]

5.—*The Direction of Glaciation as ascertained by the Form of the Striae.* Read at the Meeting of the British Association in Aberdeen, in 1885.

The greater part of the book consists of a reprint of Professor Lewis' *Field Note-books*,* under the following heads:—1. First Visit to Ireland, 1885; 2. Second Visit to Ireland, 1886; 3. Glaciation of Durham and part of Northumberland; 4. Glaciation of Yorkshire; 5. North Lancashire and Cheshire District; 6. South Lancashire, Cheshire, and Midland District; 7. Drift of the Severn, Avon, and Rugby; 8. East of England; 9. South of England; 10. Wales; 11. Isle of Man; 12. Additional References; 13. Memoranda and Brief Essays on various subjects connected with Glacial Geology.

In Appendix A, Mr. P. F. Kendall gives some valuable notes as to work done by him in the Lancashire region since Professor Lewis' death; and in Appendix B there are some brief notes by Professor Lewis on the Glacial Geology of the Continent of Europe.

1894.—Upham, Warren. Pleistocene Climatic Changes.—*Geol. Mag.*, pp. 340-349.

* As it fell to my lot to decipher and make a "fair copy" of the contents of these note-books for the printer, I can testify to the extreme interest and suggestiveness of their contents.—W. J. H.

"The Ice-age seems to me to have been essentially continuous and single, with important fluctuations, but not of epochal significance, both during its advance and decline." Thinks that the increased cold of the Glacial Epoch was due to continental elevation, which he terms "epeirogeny."

1894.—Hughes, T. McKenny. On some Sources of Error in the Study of the Drift.—*Nature* (May 3), pp. 5-6.

Some Boulders may have been brought to the points where they now occur by human agency, as wrecks of ships in ballast, &c. Landslips, also, may mingle modern shells with glacial gravels, &c.

1894.—Madsen, Victor. The Scandinavian Ice-sheet.—*Nature* (May 17), p. 54.

"The deep Skagerak channel was at first formed after or during the period of largest glaciation to which the Norwegian ice-stream belongs, but before the Baltic ice-streams." Hence this channel did not prevent the Scandinavian ice from reaching East Anglia.

1894.—Upham, Warren. Niagara River since the Ice Age.

Thinks that 7,000 to 10,000 years have elapsed since the Glacial Period.

1894.—Kelvin, Lord. Popular Lectures and Addresses: vol. II, *Geology and General Physics.* Macmillan and Co.

Publications of the Government Geological Survey.

In the later-issued or "Drift" edition of the Maps of the Survey, all the beds of boulder-clay, sand, &c., are coloured; and the stratified rocks are only indicated where they actually form the surface. It is the "Drift" edition, of course, which will be most useful to glacialists.

Maps of the Government Ordnance Survey.

The "six-inch" map is the best on which to mark the positions of boulders, &c.; and for marking down one's own observations the plain "Ordnance" sheets will be found the best. A good way to use these maps without interfering with their clearness is to make a pin-hole at the desired point, and then write the reference number or note on the *back* of the map against the pin-hole.—(P. F. Kendall.)

In reviewing the papers upon Midland Glaciology which have now been enumerated, we see that the serious study of the subject begins with Buckland's work in 1821-23; and that his observations

were continued and extended by Murchison and Strickland in 1835-40.

The first to bring ice over the Midlands is Charles Darwin in 1842, who invoked its aid (in the form of bergs) to carry the Staffordshire boulders. It is noticeable that singularly little attention was paid to the Midland Drift by the officers of the Geological Survey when they mapped the region in 1855-60. The local Survey Memoirs contain very little about it.

The year 1869 marks an epoch, for it was then that Dr. Crosskey came to Birmingham, and that Mr. C. J. Woodward joined with him in the systematic study of the Drift and the mapping of the boulders. This mapping was continued in 1873 by Mr. D. Mackintosh; and in 1888 by Mr. F. W. Martin, and it has given us information of the highest interest and importance. What is now required is the extension of these field operations on a detailed scale, and their completion.

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RECORDS

OF

METEOROLOGICAL OBSERVATIONS

TAKEN AT THE OBSERVATORY OF THE

BIRMINGHAM AND MIDLAND INSTITUTE.

BY

MR. ALFRED CRESSWELL,

CURATOR OF THE OBSERVATORY.

[The accompanying Records and Charts have been drawn up by Mr. Cresswell at the request of the Society, and are published by permission of the Council of the Midland Institute.]

Records of Meteorological Observations taken at the Observatory of the Birmingham and Midland Institute, The Monument, Waterworks Road, Edgbaston, Birmingham.

The Observatory is situated in North Latitude 52° 28′ 24″, and West Longitude 1° 55′ 40″, and is at an average elevation of 500 feet above the mean sea level.

Barometer.

The cistern of the standard barometer is 541 feet above the mean sea level, and the barometer is read twice daily, at 9 a.m. and at 9 p.m.

Temperature.

The temperatures given are the highest, lowest, and the 9 a.m. readings, from maximum and minimum thermometers, placed four feet above the ground in the shade. The solar radiation is the maximum temperature given by a blackened bulb thermometer in vacuo, exposed to the direct rays of the sun.

Rain.

The amount is given from a gauge placed one foot above the ground, and 525 feet above mean sea level.

Sunshine.

The amount of sunshine has been obtained by a Jordan's sunshine recorder, placed on the top of The Monument, about 100 feet above the ground.

Horizontal Motion of the Air.

A continuous record has been obtained by means of Robinson's hemispherical cups, in connection with Osler's anemometer, which is situated on the top of The Monument, about 100 feet above the ground; the velocity being obtained on the assumption that the cups move with one-third the velocity of the air.

Extreme Wind Pressure.

The pressure plate of Osler's anemometer, from which this record has been obtained, presents a surface of two superficial feet to the wind. The direction at the time of greatest pressure, given to the nearest sixteenth point of the compass, has also been obtained from this instrument.

For all the self-recording instruments the day begins and ends at midnight. The maximum and minimum thermometers and the rain gauge have been read twice daily, at 9 a.m. and 9 p.m. The temperatures and rainfall thus recorded may be taken generally as occurring on the day for which they are entered.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1893.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
July 1	29·528	30·103	B.	C.B.	65·6	78·6	58·3	133·0
2	29·561	30·137	C.B.	C.B.	72·3	80·3	58·0	**138·0**
3	29·581	30·157	Hz.	C.B. Th. R.	67·8	76·8	52·7	124·0
4	29·593	30·168	C.B.	C.B.	59·4	70·8	52·0	119·2
5	29·289	29·859	C.	C.B.	59·0	74·2	52·0	122·0
6	29·456	30·030	C.B.	B.	63·0	79·5	59·0	126·6
7	29·382	29·954	B.	B.	72·0	**83·7**	65·0	130·8
8	29·138	29·705	C.B.	R.	71·7	74·5	54·0	124·5
9	29·049	29·614	C.	C.B.	59·4	67·6	55·0	120·8
10	29·259	29·829	C.	C.B.R.	60·3	67·4	54·5	118·0
11	29·108	29·675	C.B.	C.Th.	60·5	66·3	55·2	120·3
12	29·036	29·601	C.	R.	58·6	63·0	55·0	98·7
13	29·124	29·691	C.	C.	56·3	62·2	51·0	98·7
14	29·294	29·864	C.	C.	54·4	58·0	49·5	94·0
15	29·394	29·966	C.	C.B.	54·3	64·9	52·6	110·0
16	29·294	29·864	O.	C.B.	53·7	62·0	53·8	102·8
17	29·319	29·890	C.	B.C.	57·4	65·2	50·0	119·5
18	29·439	30·012	C.	C. to R.	56·7	62·6	57·0	104·0
19	29·080	29·646	C.	C. to R.	60·4	67·4	55·6	106·0
20	28·947	29·510	C.B.	C.B.	61·0	68·0	53·6	117·6
21	29·133	29·700	C.B.	C.B.	62·3	69·3	50·6	122·2
22	29·324	29·895	B.C.	B.C.	58·2	67·0	51·3	121·9
23	29·525	30·100	C.	C. to R.	60·7	66.8	56·5	105·2
24	29·267	29·837	C.B.	B.C.	66·2	71·3	53·2	127·6
25	29·236	29·805	C.B.	C.B.R.	60·4	65·5	54·1	116·3
26	29·267	29·836	C.	C.B.	57·1	63·0	52·2	107·8
27	29·613	30·190	R.	C.B.	54·0	64·9	49·8	107·6
28	**29·685**	30·262	Hz.	B.C.	58·3	71·5	55·5	126·3
29	29·555	30·134	O.	C. to R.	56·8	67·6	53·3	117·5
30	29·331	29·902	O.	B.C.	55·6	64·5	51·4	121·9
31	29·312	29·883	C.	B.C.	56·0	61·8	48·1	100·9
Extreme, Mean, or Sum.	**29·685** 28·947				60·3	**83·7**	48·1	**138·0**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1893.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
July 1	...	9	0	188	7·8	1.0	*1·30*	S.S.E.
2	...	6	10	172	7·2	1·0	*8·0*	N.N.W.
3	...	4	10	199	8·3	1·0	*6·25*	N.
4	...	7	35	**420**	**17·5**	3·0	*9·10*	E.N.E.
5	...	...	50	417	17·4	3·5	*2·30*	E.N.E.
6	...	11	20	278	11·6	1·0	*12·5*	E.
7	...	**11**	**45**	240	10·0	1·5	11·0	S.S.E.
8	0·150	5	55	238	9·9	1·0	*4·40*	S.W.
9	0·010	4	30	414	17·2	**5·0**	*2·10*	W.S.W.
10	0·040	3	25	336	14·0	3·0	*2·35*	S.W.
11	0·250	1	35	212	8·8	1·5	10·10	S.S.E.
12	**0·340**	...	15	222	9·2	0·5	*3·10*	N.E.
13	0·015	...	25	188	7·8	0·5	*3·30*	N.
14	0·025	...	40	228	9·5	1·5	1·35	N.W.
15	0·030	1	35	166	6·9	...	...	...
16	0·040	...	55	116	4·8	...	...	...
17	0·030	7	15	404	16·8	5·0	*5·35*	N.W.
18	0·190	4	40	340	14·2	2·0	*4·0*	W.S.W.
19	0·210	...	30	373	15·5	3·0	*1·45*	S.W.
20	...	7	0	226	9·4	1·5	*1·45*	W.N.W.
21	...	4	10	170	7·1	...	...	...
22	...	8	30	284	11·8	1·0	9·15	W.N.W.
23	0·105	...	...	270	11·2	2·0	12·0 noon	S.S.W.
24	...	4	40	330	13·7	2·0	9·40	W.S.W.
25	0·025	4	45	418	17·4	3·0	*5·20*	W.
26	0·065	2	50	311	13·0	2·5	*2·25*	N.W.
27	...	1	30	160	6·7	...	...	...
28	...	5	15	197	8·2	1·0	10·45	S.
29	0·120	...	50	203	8·5	1·0	*4·30*	N.W.
30	...	5	25	400	16·6	3·0	*1·30*	N.N.W.
31	...	3	10	419	17·5	3·0	*12·25*	N.N.W.
Extreme, Mean, or Sum.	1·645	130	35	8,539	11·5	**5·0**	*2·10*	W.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1893.	Corrected for Tempera-ture.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radia-tor Max.
Aug. 1	29·431	30·004	C.	C.B. to R.	56·2	62·3	55·1	107·3
2	29·297	29·868	C.	C.B.	61·2	65·3	56·6	113·8
3	29·173	29·742	C.	C. to R. to B.	59·8	69·2	55·7	127·6
4	29·120	29·687	C.	B.C.R.	57·4	64·6	53·6	117·0
5	29·271	29·841	C.	B.C.	57·4	63·0	45·3	115·9
6	29·527	30·102	B.C.	B.C.toC.toR.	56·1	64·6	52·8	113·8
7	29·427	30 000	B.C.	B.C. to B.	64·1	75·5	58·6	129·0
8	29·543	30·118	C.	C.B.	68·4	80·2	59·6	130·2
9	29·499	30·073	B.	B. to **Th.** H. & R.	72·2	81·5	62·3	125·1
10	29·345	29·916	C.	C.B. to B.C. TH.	69·3	81·3	55·6	126·8
11	29·496	30·070	C.	C. to R.	62·8	71·6	62·8	121·0
12	29·570	30·146	C.	C.B.	65·5	77·8	60·0	131·3
13	29·624	30·201	Hz.	B.C.	68·1	80·4	60·7	131·1
14	29·667	30·245	B.C.	B.C.	68·2	82·2	65·0	128·0
15	29·640	30·217	B.C.	B.	72·7	84·0	62·5	127·0
16	29·539	30·114	B.	B.	70·8	80·8	59·9	123·1
17	29·492	30·066	B.	B.	68·7	84·5	62·5	131·0
18	29·194	29·762	B.	B. to C.B.	74·4	**85·6**	58·8	**131·7**
19	29·295	29·865	C.B.	B. to C. to R.	63·1	74·2	58·5	124·6
20	29·138	29·705	R.	C. to B.C.	64·3	71·5	61·0	122·4
21	28·943	29·506	C.B.	B.C.	61·0	69·3	53·5	119·9
22	29·213	29·782	C.B.	B.C.R.	60·0	69·4	51·9	120·5
23	29·348	29·919	B.C.	B.C.R.	60·7	68·8	50·7	123·6
24	29·415	29·988	B.C.	B.C.R.	58·7	66·4	50.0	119·8
25	29·670	30·248	B.C.	C.B.	57·7	65·5	48·2	108·6
26	29·693	30·271	C.B.	C.	55·7	64·0	49·8	116·7
27	29·587	30·163	R.	C.	51·5	62·1	44·0	112·3
28	29·738	30·317	C.	C.B.	52·8	64·1	45·6	116·0
29	**29·751**	30·331	O.	C.B.	54·0	67·8	44·1	107·5
30	29·609	30·186	B.C.	B.C.	59·7	69·3	56·0	110·0
31	29·413	29·986	O.	O. to R.	57·4	64·1	53·2	97·3
Extreme, Mean, or Sum.	**29·751** 28·943				62·2	**85·6**	44·0	**131·7**

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Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1893.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Aug. 1	0·040	3	0	251	10·5	1·0	8·40	N.W.
2	...	3	10	328	13·7	1·5	*5·10*	W.N.W.
3	0·215	1	30	462	19·2	5·5	9·10	S.W.
4	0·100	5	0	328	13·7	2·5	11·40	W.S.W.
5	...	9	25	438	18·2	3·5	*3·10*	N.W.
6	0·150	3	50	237	9·9	1·0	*11·20*	S.S.W.
7	0·010	9	50	324	13·5	2·0	*12·40*	S.W.
8	...	6	25	199	8·3	...	...	...
9	0·720	**12**	**15**	349	14·5	2·2	11·35	S.E.
10	0·120	6	35	266	11·1	2·0	*7·0*	W.S.W.
11	0·260	2	35	238	9·9	1·2	*2·10*	S.S.W.
12	...	3	50	145	6·0	...	...	...
13	...	5	0	92	3·8	...	...	...
14	...	9	20	131	5·5	...	...	...
15	...	10	30	196	8·2	...	...	...
16	...	11	35	193	8·0	...	...	...
17	...	10	20	176	7·3	1·0	*4·30*	S.S.W.
18	...	8	35	265	11·0	2·0	*12·5*	S.S.W.
19	0·180	5	45	308	12·8	3·5	*3·10*	S.W.
20	0·170	5	5	434	18·1	4·0	11·0	S.S.W.
21	...	7	15	**548**	**22·8**	6·0	11·30	W.S.W.
22	0·040	6	25	390	16·2	**6·5**	*3·50*	W.S.W.
23	0·050	6	50	246	10·3	2·5	*5·40*	W.
24	0·020	9	50	420	17·5	4·5	*4·30*	W.S.W.
25	...	5	55	305	12·7	1·0	*3·40*	N.N.W.
26	0·100	3	15	326	13·6	1·2	11·40	N.W.
27	0·010	1	5	241	10·0	0·5	*5·40*	N.N.E.
28	...	4	40	216	9·0	0·5	10·12	N.E.
29	...	4	0	188	7·8	0·5	*3·30*	N.E.
30	...	9	50	327	13·6	1·5	*6·50*	N.N.W.
31	0·070	...	15	348	14·5	1·8	8·0	N.N.W.
Extreme Mean, or Sum.	2·255	192	55	8,915	11·9	**6·5**	*3·50* Ital. = P.M.	W.S.W.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at th

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hai

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1893.	Corrected for Tempera-ture.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radia-tion. Max.
Sept. 1	29·476	30·050	O.	C.	54·2	62·7	54·2	98·2
2	29·548	30·123	C.	C.B.	58·6	67·4	52·9	108·8
3	29·716	30·295	C.B.	C.	59·5	67·9	55·0	108·6
4	29·643	30·231	B.	B.	62·3	71·6	48·0	117·8
5	29·440	30·013	B.	B.C.	58·0	73·7	56·1	**127·9**
6	29·244	29·813	C.B.	C. to B.C. to C. to R.	62·0	**73·8**	56·5	119·9
7	29·166	29·734	C.B.	C.B.	63·2	67·5	52·6	117·9
8	29·102	29·669	C.B.	C.B. to R.	58·3	61·9	47·3	110·0
9	29·334	29·905	C.	C.	53·0	57·0	41·9	96·8
10	29·451	30·025	C.B.	C.B.	51·3	58·5	41·4	108·9
11	29·680	30·258	C.B.	C.B.	52·3	62·1	40·6	107·8
12	**29·771**	30·351	C.B.	B.C.Hz.	51·7	61·2	44·7	100·7
13	29·627	30·204	B.C.Hz.	B.C.	55·5	68·0	55·5	108·2
14	29·662	30·240	C.	C. to B.C.	61·2	70·0	50·6	115·0
15	29·591	30·167	C.	C. to B.C.	58·5	71·0	50·6	117·0
16	29·347	29·918	O.	C.	56·2	62·1	46·4	90·3
17	29·205	29·774	C.	C.B.	54·0	59·7	53·0	102·0
18	29·081	29·647	C.	C.	56·0	63·0	56·1	85·2
19	28·853	29·415	C.B.	C.R.	59·7	66·5	42·8	111·9
20	28·853	29·415	B.C.	C.B. to R.	49·8	59·0	39·0	111·3
21	28·959	29.523	C.B.	C.B.	42·8	54·1	40·3	99·5
22	29·044	29·609	C.B.	C.B.	50·0	56·0	39·3	101·6
23	28·971	29·535	C.	C.B.Th. with H.	42·0	50·5	39·9	101·0
24	29·399	29·971	B.	C.B.	46·6	54·7	42·0	103·0
25	29·388	29·960	D.	C.	49·1	54·0	47·0	77·7
26	29·355	29·927	C.B.	C. to R.	54·0	61·3	51·8	109·0
27	29·207	29·776	C.	C.	54·6	60·4	47·1	79·5
28	29·141	29·708	O.	R.	51·0	58·0	49·5	79·7
29	28·690	29·248	B.C.	C.B. with R.	54·3	59·0	44·5	107·0
30	28·655	29·213	C.B.	C.B.	50·7	59·7	45·0	110·3
Extreme, Mean, or Sum.	**29·771** 28·655				54·3	**73·8**	39·0	127·

NOTE.—Heavy type indicates maximum or in large quantities

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1893.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Sept. 1	...	...	10	226	9·4	1·6	*11·25*	W.N.W.
2	...	3	0	392	16·3	2·6	9·25	N.W.
3	...	1	55	102	4·2	...	...	...
4	...	9	5	165	6·9	...	...	...
5	...	**9**	**10**	167	7·0	...	...	...
6	0·180	3	40	260	10·8	0·8	*5·35*	W.S.W.
7	...	7	25	402	16·7	3·2	*12·20*	W.
8	0·200	3	25	376	15·7	5·5	*9·20*	N.N.W.
9	...	1	55	240	10·0	1·8	*3·10*	N.W.
10	...	7	40	283	11·8	1·9	*4·40*	E.N.E.
11	...	6	5	272	11·3	1·1	10·50	E.
12	...	6	20	135	5·6	...	...	...
13	...	7	50	309	12·9	2·4	*3·5*	W.
14	...	5	55	254	10·6	0·8	*3·5*	N.W.
15	...	4	35	240	10·0	0·8	*2·30*	W.S.W.
16	...	...	20	207	8·6	1·0	*7·50*	N.N.W.
17	0·010	3	20	292	12·2	1·1	*4·50*	W.N.W.
18	0·015	...	10	268	11·2	1·0	*8·25*	S.W.
19	0·020	...	55	385	16·0	5·0	*1·35*	W.S.W.
20	0·065	7	0	242	10·1	1·4	*10·0*	W.N.W.
21	...	5	45	198	8·2	...	...	...
22	0·035	5	50	350	14·6	3·5	*1·10*	N.W.
23	0·090	4	20	388	16·2	5·0	*12·30*	W.
24	0·005	6	55	336	14·0	1·5	12·30	W.N.W.
25	0·020	...	10	306	12·7	3·3	7·10	W.N.W.
26	0·500	1	45	286	11·7	1·8	11·30	S.W.
27	0·025	...	10	278	11·6	1·4	*4·30*	W.N.W.
28	**0·470**	...	...	**464**	**19·3**	5·0	*8·25*	S.S.W.
29	0·055	7	5	444	18·5	**5·8**	*4·20*	S.W.
30	0·035	6	45	321	13·4	1·8	11·0	W.S.W.
Extreme Mean, or Sum.	1·725	128	40	8,588	11·9	**5·8**	*4·20*	S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at th

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hai

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1893.	Corrected for Tempera-ture.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radia-tion. Max.
Oct. 1	29·007	29·572	C.B.	B.C. to C.R.	49·7	61·5	42·3	110·6
2	29·024	29·589	C.B.	B.C.R.	47·0	57·0	40·2	101·6
3	28·774	29·334	B.	B. to C.B. R.	45·0	53·9	41·6	107·3
4	28·548	29·103	C.	R. to C.B.	46·3	53·1	43·8	100·0
5	28·668	29·226	B.C.	B.C. to R.	47·1	55·9	43·0	101·1
6	28·869	29·431	B.	B.C. to R.	46·7	57·5	42·6	103·7
7	28·980	29.544	C.B.	C.B. to R.	50·2	57·6	44·7	105·1
8	29·093	29·659	B.	B.C.	51·0	59·0	41·4	107·4
9	29·197	29·765	M.	C.	44·9	55·9	44·1	84·7
10	29·238	29·807	B.C.	C.B. to R.	48·0	56·0	46·4	100·6
11	29·225	29·794	B.C.	B. to C.	48·4	52·4	42·5	72·6
12	29·449	30·022	B.	B.C.	46·1	53·6	39·2	95·0
13	29·596	30·172	C.	C.B. to R.	44·6	58·7	44·5	101·1
14	29·232	29·801	C.	C.R.	58·3	63·3	57·4	101·9
15	29·329	29·900	C.	C.	59·8	63·3	55·9	91·2
16	29·319	29·890	C.	C.B.	57·9	64·4	51·0	**112·0**
17	29·489	30·063	R.	R.	52·4	54·6	44·0	61·1
18	29·578	30·154	O.	C.	45·6	53·3	42·8	73·7
19	28·785	30·365	C.B.	C.B. to C.	47·4	54·6	42·7	77·3
20	29·767	30·347	C.B.	C.B.	47·4	57·4	47·5	92·2
21	29·614	30·201	C.B.	C.B. to R.	55·5	**64·7**	46·1	110·0
22	29·648	30·225	O.	C. to B.C.	49·0	53·4	42·6	91·1
23	**29·861**	30·443	C.	C.	47·2	52·2	45·1	69·6
24	29·772	30·352	C.	C.	46·4	53·0	46·4	80·3
25	29·384	29·956	C.	C. to R.	49·0	54·2	43·0	74·8
26	29·207	29·776	B.	B. to C.	45·1	49·7	39·0	91·0
27	29·370	29·942	B.	B.C.	42·7	51·6	42·6	91·5
28	29·282	29·852	C.	C.	50·4	54·5	43 0	75·6
29	29·178	29·746	C.B.	C.B.	54·6	50·7	34·2	82·8
30	29·321	29·892	B.	C.B.	37·0	44·1	29·6	77·5
31	29·552	30·128	B.	B.C.	32·6	39·7	29·0	65·4
Extreme, Mean, or Sum.	**29·861** 28·548				47·9	**64·7**	29·0	**112·0**

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DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1893.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Oct. 1	0·140	5	0	190	7·9	0·6	*2·0*	S.W.
2	0·035	5	35	210	8·7	1·5	*1·25*	S.W.
3	0·180	7	30	281	11·7	2·0	*1·40*	W.
4	0·235	1	55	307	12·8	3·0	*1·10*	W.
5	0·115	6	45	234	9·7	1·0	*1·35*	S.W.
6	0·125	6	45	211	8·8	0·5	*6·10*	S.S.W.
7	0·080	2	30	145	6·0	...	...	...
8	...	7	35	187	7·8	...	...	...
9	...	...	10	175	7·3	...	...	...
10	0·285	4	25	303	12·6	2·0	*11·50*	S.S.E.
11	...	1	30	294	12·2	3·2	4·55	S.S.W.
12	...	5	20	296	12·3	1·2	11·5	W.N.W.
13	**0·450**	2	20	330	13·7	3·6	*10·20*	S.S.W.
14	0·030	1	50	470	19·6	4·4	10·40	W.S.W.
15	...	...	10	485	20·2	5·0	4·30	W.S.W.
16	...	3	45	397	16·5	3·0	10·35	W.S.W.
17	0·355	...	...	214	8·9	1·0	*10·55*	E.N.E.
18	...	...	...	155	6·5	...	...	...
19	. .	2	55	112	4·7	...	...	...
20	0·010	2	35	233	9·7	0·6	*1·20*	S.W.
21	0·024	3	20	340	14·2	2·6	*8·0*	W.S.W.
22	...	4	5	226	9·4	0·5	11·30	N.N.W.
23	...	...	15	168	7·0	...	...	...
24	...	...	20	272	11·3	1·0	*3·35*	W.S.W.
25	0·110	...	15	463	19·3	4·5	*3·0*	S.W.
26	0·025	4	55	455	19·0	5·4	*4·35*	W.
27	...	6	15	369	15·4	1·8	11·55	W.N.W.
28	0·015	...	15	**488**	20·3	**7·5**	*4·5*	W.S.W.
29	0·020	3	0	301	12·5	4·0	*12·30*	W.N.W.
30	...	2	30	213	8·9	...	...	...
31	...	3	45	208	8·7	...	...	...
Extreme, Mean, or Sum.	2·450	97	30	8,732	11·6	**7·5**	*4·5* Ital. = P.M.	W.S.W.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1893.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Nov. 1	29·281	29·851	C.	C.	35·9	48·8	36·0	52·4
2	29·075	29·641	O.	C.	43·7	49·0	43·0	59·0
3	29·262	29·832	C.	C.	48·0	**57·7**	46·1	**92·0**
4	29·323	29·894	C.	C.	46·1	46·6	28·3	52·9
5	29·328	29·899	B.	B. to C.	35·4	44·6	29·4	84·5
6	29·471	30·045	C.B.	C.B.	31·5	43·8	30·1	70·8
7	29·717	30·296	C.B.	C.B.	32·0	43·0	32·0	67·0
8	29·769	30·349	C.	C.B. to C.	35·6	42·5	35·5	64·0
9	29·736	30·315	O.	C. to B.C.	39·8	43·6	35·5	80·2
10	29·722	30·301	O.	O.	40·5	44·1	40·5	48·4
11	29·784	30·364	O.	O.	43·5	47·4	39·6	57·7
12	29·802	30·383	C.	C. to B.C.	42·3	45·9	34·0	78·0
13	29·532	30·107	O.	C. to B.C.	35·2	43·0	27·1	71·2
14	29·247	29·816	F.	F. to R.	30·5	38·0	30·0	44·4
15	29·209	29·778	R.	C.	37·5	43·9	37·4	45·0
16	29·261	29·831	O.	C. to R.	41·3	53·9	41·3	53·5
17	28·472	29·026	C.	R.	51·6	52·3	36·5	64·0
18	28·539	29·094	R.	R. to S.	36·8	39·6	25·9	38·0
19	29·170	29·738	C.B.	B.C. to C.	27·5	38·0	27·5	63·0
20	29·538	30·113	C.B.	C.B.	35·6	39·6	34·1	65·2
21	**29·896**	30·478	O.	C.	36·0	40·0	34·0	42·6
22	29·540	30·115	C.	C.B.R.	38·0	44·1	27·0	69·0
23	29·538	30·113	B.C.	C.B. to C.	28·3	44·0	28·2	51·3
24	29·536	30·111	C.	C.	43·2	46·0	41·8	53·6
25	29·256	29·827	C.	C. to R.	45·0	49·3	40·7	52·0
26	29·064	29·630	C.	C.	40·5	42·1	29·0	54·7
27	29·711	30·290	C.B.	C.	32·4	49·6	32·4	51·0
28	29·674	30·252	C.B.	C.B.	49·1	54·0	47·2	85·8
29	29·619	30·196	C.	C.	47·3	49·3	43·5	72·2
30	29·261	29·831	C.	C.	44·0	47·0	32·6	54·5
Extreme, Mean, or Sum.	**29·896** 28·472				39·1	**57·7**	25·9	**92·0**

NOTE.—Heavy type indicates maximum or in large quantities ;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1893.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Nov. 1	0·100	...	...	388	16·2	3·0	*12·10*	S.W.
2	...	...	...	245	10·2	0·5	1·30	W.S.W.
3	0·020	...	10	355	14·8	2·0	*10·20*	W.S.W.
4	...	...	...	309	12·9	3·5	6·35	N.N.W.
5	...	**5**	**25**	235	9·4	1·3	*1·55*	W.
6	...	2	30	349	14·5	2·0	*4·0*	N.N.E.
7	...	3	0	309	12·9	1·5	*1·20*	N.E.
8	0·005	1	20	282	11·7	1·8	6·20	N.N.E.
9	...	2	0	433	18·0	4·0	*4·20*	E.N.E.
10	...	...	...	416	16·9	3·5	10·0	E.N.E.
11	...	...	...	338	14·1	2·0	*2·25*	E.N.E.
12	...	2	25	363	15·1	2·0	*2·5*	E.
13	...	2	0	235	9·8	0·5	*12·30*	E.S.E.
14	0·080	...	...	93	3·9	...	...	...
15	...	...	...	234	9·8	...	...	...
16	0·130	...	...	411	17·1	6·5	*11·30*	S.S.E.
17	0·180	...	...	464	19·3	7·4	7·0	S.S.W.
18	*0·170*	...	...	**756**	**31·5**	**13·0**	11·30	N.
19	*0·020*	2	40	725	30·2	7·5	*3·25*	N.N.W.
20	...	1	15	508	21·2	5·0	*1·10*	N.E.
21	...	...	...	265	11·0	0·5	*1·0*	N.N.E.
22	0·010	1	50	438	18·2	7·0	*12·20*	N.W.
23	..	2	0	469	19·5	4·0	6·25	N.N.W.
24	0·010	...	...	391	16·3	2·0	*12·25*	N.W.
25	**0·460**	...	...	422	17·6	4·0	*4·0*	W.S.W.
26	...	...	20	495	20·6	5·0	*2·10*	N.
27	...	...	5	306	12·7	2·0	*5·20*	W.
28	...	2	15	435	18·1	3·0	*2·40*	W.N.W.
29	...	...	35	580	24·2	7·4	*2·35*	W.S.W.
30	0·200	...	...	321	13·4	2·5	6·10	S.W.
Extreme, Mean, or Sum.	1·385 Ital. = Snow melted.	29	50	11,570	16·1	**13·0**	11·30 Ital. = P.M.	N.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1893.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Dec. 1	29·236	29·805	Sleet.	C.B.	33·4	35·9	22·0	55·3
2	29·830	30·411	B.	C.B.	25·2	36·0	25·0	51·2
3	29·769	30·349	C.	C.B.	35·3	45·0	33·9	56·4
4	29·624	30·201	O.	C. to R.	39·0	46·9	38·4	49·0
5	29·765	30·345	C.F.	C.	39·8	46·1	39·2	47·0
6	29·487	30·061	C.	C.	45·3	49·6	39·0	68·6
7	29·091	29·657	B.	B.	39·4	49·0	35·7	77·0
8	28·697	29·255	R.	C.	43·7	49·5	34·0	55·7
9	28·718	29·277	B.	B.C.	34·7	42·8	31·0	74·3
10	28·751	29·310	O.	R.	35·8	46·5	34·2	46·7
11	28·816	29·377	C.	B.C.	34·2	41·4	31·7	69·0
12	28·781	29·341	R.	R.	41·0	49·9	35·5	51·0
13	28·418	28·971	B.C.	B.C.toC.&R.	49·5	**51·3**	35·8	59·1
14	29·180	29·748	C.B.	B.C.	35·8	41·5	33·6	64·6
15	29·675	30·253	C.B.	C.B. to R.	39·1	49·7	39·1	53·7
16	29·837	30·418	C.	C.B.	48·1	50·3	37·0	**78·5**
17	29·711	30·290	C.B.	C.	40·7	43·0	37·0	53·0
18	29·407	29·980	O.	C.B. to R.	38·6	46·6	38·3	65·0
19	28·829	29·390	O.	R.	44·2	45·0	35·0	46·2
20	28·208	28·757	R.	R.	35·5	45·6	33·0	71·0
21	28·815	29·376	B.	B.	36·0	41·0	33·8	70·8
22	29·097	29·663	C.	R.	39·0	49·6	37·5	51·4
23	29·510	30·085	B.C.	B.C.	38·0	46·0	38·0	69·8
24	29·525	30·100	C.	C.R.	41·5	49·0	39·3	49·3
25	29·514	30·089	B.C.	B.C.	40·6	45·6	35·4	73·1
26	29·803	30·384	C.	C.	38·7	44·7	38·0	65·0
27	29·784	30·364	C.	C.	40·6	45·0	40·3	57·4
28	29·938	30·521	C.	C.	40·7	44·8	39·9	55·2
29	30·067	30 653	O.	C.	39·9	42·5	30·1	44·6
30	**30·133**	30·720	F.	O.F.	31·4	34·2	26·5	36·5
31	29·945	30·528	M.	C. to R.	33·1	41·7	33·0	58·1
Extreme, Mean, or Sum.	**30·133** 28·208				38·6	**51·3**	22·0	**78·5**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1893.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Dec. 1	...	1	30	417	17·4	2·0	11·10	N.N.W.
2	...	1	55	186	7·7	...	...	...
3	...	1	30	285	11·9	...	...	...
4	0·050	...	...	383	16·0	2·0	*2·10*	N.N.W.
5	...	...	...	176	7·3	...	...	...
6	0·050	...	40	415	17·3	4·0	*1·30*	W.S.W.
7	0·180	5	15	450	18·7	5·0	4·30	W.
8	0·150	...	...	598	24·9	**14·0**	7·25	S.S.W.
9	0·010	4	35	272	11·3	1·0	12·30	W.S.W.
10	0·165	...	...	442	18·4	13·0	*12·35*	S.S.E.
11	0·070	4	40	249	10·4	1·6	8·35	W.N.W.
12	**0·760**	...	...	423	17·6	7·5	*12·30*	S.
13	0·160	...	40	560	23·3	12·0	*2·20*	S.W.
14	...	3	50	395	16·5	3·0	5·20	N.N.W.
15	...	...	40	400	16·6	3·0	6·30	S.S.W.
16	...	1	15	432	18·0	4·0	2·0	S.W.
17	...	1	15	283	11·8	2·5	*10·20*	S.S.E.
18	0·090	...	50	275	11·5	1·0	*2·20*	S.
19	0·480	...	...	**632**	**26·3**	10·0	10·20	S.
20	0·320	...	20	468	19·5	4·0	*10·40*	N.W.
21	0·050	**5**	**35**	446	18·6	3·0	11·55	W.
22	0·200	...	...	482	20·1	7·5	*3·50*	W.N.W.
23	...	4	40	276	11·5	1·0	*12·35*	W.S.W.
24	0·105	...	...	466	19·4	8·0	*10·40*	S.W.
25	0·085	4	10	507	21·1	7·5	12·25	W.S.W.
26	...	1	5	208	8·7	0·5	3·55	W.
27	...	...	40	204	8·5	1·0	*10·55*	S.
28	...	...	...	160	6·6	...	...	...
29	...	...	...	106	4·4	...	...	...
30	...	...	...	80	3·3	...	...	...
31	0·100	...	20	201	8·4	...	...	...
Extreme Mean, or Sum.	3·025	45	25	10,877	14·6	**14·0**	7·25	S.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Tempera-ture.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radia-tion. Max.
Jan. 1	29·777	30·357	C.B.	C.B.	35·2	37·2	30·1	55·4
2	29·679	30·257	C.B.	C.	31·7	34·4	33·8	40·4
3	**30·002**	30·587	C.B.	C. to S.	25·0	29·0	24·2	40·7
4	29·689	30·267	C.	C.	25·2	26·1	17·6	52·0
5	29·227	29·796	O.	C.	18·0	19·2	10·8	48·0
6	29·047	29·612	F.	C.	18·5	26·0	17·0	38·0
7	29·270	29·840	O.	C.	25·2	27·0	20·3	34·4
8	29·424	29·997	O.	C. to S.	24·0	36·8	24·0	36·8
9	29·145	29·712	O.	C.	36·8	42·7	34·6	43·0
10	29·123	29·690	O.	C.	42·4	47·5	42·0	50·0
11	29·151	29·718	O.	B.C.	45·9	**53·6**	43·0	**86·5**
12	29·280	29·850	B.	B.C.	43·3	50·0	41·9	79·8
13	29·332	29·903	O.	C.	43·9	45·0	42·0	48·3
14	29·182	29·750	O.	C. with D.	43·0	45·0	34·4	50·5
15	29·420	29·993	B.	B. to C. with R.	35·4	46·1	35·2	59·0
16	29·221	29·790	C.B.	C. with R.	42·4	48·5	42·3	70·4
17	28·961	29·525	C.	C. with R.	45·8	50·0	39·0	81·7
18	28·876	29·438	C.B.	C.	39·6	47·0	38·0	83·1
19	29·275	29·845	C.	C. to R.	38·5	48·4	38·4	64·9
20	28·873	29·435	B.C.	C.	42·6	47·0	38·7	84·2
21	29·308	29·879	C.	C.	42·5	47·7	38·4	81·6
22	28·952	29·516	O.	C.	38·6	40·9	32·4	58·3
23	29·226	29·795	B.	R.B.	32·9	36·3	26·0	62·5
24	29·483	30·057	C.B.	C.	31·4	45·0	31·2	46·0
25	29·254	29·823	C.	C.	43·2	45·0	33·0	63·7
26	29·076	29·642	B.	B C.	34·0	47·3	34·0	79·3
27	29·052	29·617	C.	C.R.	46·5	50·0	33·5	61·3
28	29·010	29·575	B.	B.C.	33·5	39·6	33·3	84·5
29	29·397	29·969	C.	B.C. to R.	37·6	44·4	36·1	80·9
30	29·060	29·626	B.C.	B.C. to R.	38·5	44·8	33·0	86·0
31	28·741	29·300	O.	C.	34·1	38·0	31·2	70·5
Extreme, Mean, or Sum.	**30·002** 28·741				36·0	**53·6**	10·8	**86·5**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Jan. 1	...	1	20	309	12·9	2·5	2·30	N.N.E.
2	...	...	...	435	18·1	3·5	*2·20*	E.N.E.
3	*0·020*	...	...	361	15·0	1·3	*1·40*	E.N.E.
4	*0·010*	...	40	574	23·9	7·0	*2·5*	E.
5	*0·010*	...	...	412	17·2	4·0	6·20	E.
6	...	...	...	146	6·1	...	...	...
7	...	...	...	91	3·8	...	...	...
8	*0 050*	...	...	267	11·1	2·0	*10·30*	S.E.
9	...	...	...	318	13·3	6·0	12·30	S.S.E.
10	0·015	...	...	384	16·0	2·5	6·30	S.S.E.
11	0·060	4	30	442	18·4	3·5	11·0	S.S.W.
12	0·070	6	0	346	14·4	3·0	*10·40*	S.
13	0·025	...	...	405	16·9	2·5	12·30	S.
14	0·070	...	...	197	8·2	...	...	...
15	0·100	1	40	360	15·0	5·0	*7·5*	S.
16	0·140	...	55	336	14·0	3·0	*2.20*	S.S.W.
17	0·165	1	40	451	18·8	8·5	*3·30*	S.W.
18	0·015	2	0	384	16·0	2·0	*2·30*	W.
19	**0·210**	...	25	505	21·2	8·4	*9·20*	S.S.W.
20	0·010	2	40	558	23·3	8·8	*1·30*	W.S.W.
21	0·130	1	15	432	18·0	6·0	*3·25*	W.S.W.
22	...	...	10	288	12·0	1·6	3·0	S.W.
23	...	2	35	351	14·6	2·0	3·50	N.N.W.
24	0·020	...	...	408	17·0	3·0	2·0	S.W.
25	0·090	...	...	259	10·8	1·5	*12·30*	S.W.
26	...	5	20	445	18·5	3·0	11·40	W.N.W.
27	0·105	...	10	**716**	**29·8**	**12·0**	2·0	W.S.W.
28	...	4	40	550	22·9	7·0	*3·20*	W.
29	0·100	4	15	416	17·3	9·0	*8·30*	S.S.W.
30	0·195	3	35	494	20·6	7·0	*10·50*	S.S.W.
31	...	...	50	180	7·5	1·0	1·0	W.S.W.
Extreme, Mean, or Sum.	1·610	44	40	11,823	15·9	**12·0**	**2·0**	W.S.W.
	Ital. = Snow melted.						Ital. = P.M.	

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Feb. 1	29·227	29·796	B.	B. to C. & R.	32·3	48·5	31·2	60·0
2	29·346	29·917	C.	C.	49·0	51·5	47·9	73·7
3	29·384	29·956	B.	C.B.	43·3	50·0	39·9	88·6
4	29·796	30·377	B.C.	B. to C.	39·4	53·8	35·1	**98·2**
5	29·807	30·388	C.	C.R.	42·0	48·0	37·2	52·2
6	29·516	30·091	O.	C.	43·0	51·0	32·6	55·0
7	29·217	29·786	B.C.	C.B. to C.	51·5	**54·4**	48·6	80·5
8	29·597	30·173	B.	B.C.	40·4	53·5	38·6	90·0
9	29·200	29·769	C.	C.	41·4	50·5	38·2	67·7
10	29·111	29·678	C.	C.	43·9	47·0	40·7	61·8
11	28·871	29·432	C.	C.	49·3	50·6	43·2	73·7
12	28·838	29·399	B.	C.B.	39·0	49·6	34·2	80·1
13	29·364	29·935	C.	C.B.	34·8	42·1	33·2	78·5
14	29·473	30·047	M.	C.	34·0	40·0	32·3	60·0
15	29·516	30·091	O.	O.	38·9	45·6	35·7	63·6
16	29·434	30·007	O.	O.	39·8	46·1	37·4	53·8
17	29·492	30·066	R.	R. to S.	42·3	44·0	31·6	43·4
18	29·771	30·350	O.	C. to C.B.	30·8	34·0	28·0	78·5
19	**29·926**	30·509	B.	B.	24·8	37·2	22·5	83·0
20	29·881	30·463	B.	B. to C.	26·0	38·0	21·9	83·3
21	29·731	30·310	B.	B. to C.	24·5	38·4	21·7	72·5
22	29·742	30·321	M.	C.B.	30·0	38·5	29·0	72·7
23	29·362	29·933	C.	C. to R.	33·4	43·6	28·8	68·3
24	29·043	29·608	C.B.	B.C.	37·6	43·6	34·9	86·8
25	29·094	29·660	R.	R. to C.	38·3	51·6	38·0	68·0
26	29·052	29·618	O.	C.	45·8	53·5	45·2	79·0
27	29·173	29·741	C.B.	B.C.	45·3	51·0	35·0	**98·2**
28	29·286	29·856	C.	C. to C.B.	37·9	44·5	34·3	90·7
Extreme, Mean, or Sum.	**29·926** 28·838				38·5	**54·4**	21·7	**98·2**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Feb. 1	0·100	3	20	456	19·0	5·3	*8·25*	W.
2	...	1	0	664	27·7	12·0	*12·35*	W.S.W.
3	0·030	4	45	507	21·1	4·5	*12·5*	W.N.W.
4	...	4	45	375	15·6	3·4	*8·30*	W.S.W.
5	0·050	...	...	156	6·5	...	...	...
6	...	...	...	598	24·9	12·0	*11·10*	W.S.W.
7	...	2	10	**903**	**37·6**	15·0	1·30	W.S.W.
8	...	6	55	459	19·1	6·0	12·30	W.
9	0·010	...	5	514	21·4	9·0	11·35	W.S.W.
10	0·030	...	10	588	24·5	7·5	*11·40*	W.S.W.
11	0·045	...	10	897	37·4	**27·5**	*10·30*	W.
12	0·010	3	10	718	29·9	21·0	3·0	W.
13	...	4	50	328	13·7	2·0	2·5	W.N.W.
14	0·010	1	15	167	7·0	...	...	...
15	0·070	...	...	183	7·6	...	...	...
16	...	...	...	199	8·3	...	...	...
17	1·100	...	...	290	12·1	1·5	8·25	S.S.E.
18	*0·170*	1	40	353	14·7	1·0	*2·20*	E.
19	...	**8**	**0**	180	7·5	...	...	...
20	...	4	20	123	5·1	...	...	...
21	...	4	10	126	5·3	...	...	...
22	...	3	20	158	6·6	...	...	...
23	**0·210**	...	30	443	18·5	7·0	*8·25*	S.W.
24	0·010	5	25	342	14·2	3·5	11·30	W.N.W.
25	0·130	...	15	554	23·1	9·5	7·20	W.S.W.
26	...	...	35	658	27·4	8·0	*11·55*	W.S.W.
27	0·050	3	15	522	21·7	9·0	*12·30*	W.
28	0·030	1	45	288	12·0	2·5	*3·0*	W.N.W.
Extreme, Mean, or Sum.	2·055 Ital. = Snow melted.	65	50	11,749	17·5	**27·5**	*10·30* Ital. = P.M.	W.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at th

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Mar. 1	29·177	29·745	C.	R.	44·3	46·0	36·0	52·0
2	29·381	29·953	B.	B.C.	39·1	48·0	36·4	99·0
3	29·568	30·144	Hz.	B. to C.	32·5	48·4	31·8	102·3
4	29·385	29·957	B.	C.B.	37·7	47·4	33·5	94·0
5	29·704	30·283	B.	C.B.	37·3	45·8	33·5	84·2
6	29·035	29·600	C.	C.B.	44·1	47·7	40·2	79·4
7	29·268	29·838	O.	C.R.	35·9	44·0	34·3	83·0
8	28·952	29·516	O.	C.	44·6	47·1	38·5	70·2
9	28·906	29·467	O.	C. to R.	43·8	48·2	37·0	59·8
10	29·030	29·595	C.	C.B.	43·8	50·0	39·6	100·0
11	28·801	29·362	B.C.	C.B.	47·0	49·5	36·3	102·8
12	28·974	29·537	B.	B.C.toC.&R.	39·8	45·1	35·8	71·0
13	28·536	29·091	B.C.	C.B.R.	38·0	47·0	35·8	100·0
14	28·931	29·494	C.	C.B.	40·5	47·3	35·4	89·3
15	28·904	29·467	Hz.	C.B.	40·4	45·3	35·8	77·3
16	29·270	29·840	B.	B.C.	38·6	46·4	32·5	89·5
17	29·624	30·201	M.	M.	32·0	48·6	29·9	58·3
18	29·719	30·298	B.	B. to C.	41·1	49·0	33·8	80·9
19	29·737	30·316	O.	O.	44·4	50·6	40·9	75·4
20	29·728	30·287	O.	O.	45·1	46·6	42·3	64·8
21	29·696	30·274	HZ.	C.	44·6	48·7	40·8	80·2
22	29·796	30·376	HZ.	C.	36·9	44·0	35·0	44·0
23	**29·896**	30·478	HZ.	C. to B.	36·0	51·3	33·1	90·4
24	29·806	30·387	F.	B.C. to B.	36·8	55·0	35·5	100·8
25	29·605	30·182	HZ.	B.	42·8	59·4	36·9	104·5
26	29·474	30·047	HZ.	B.	42·0	**63·3**	35·0	107·9
27	29.519	30·094	F.	B.	44·1	61·4	35·9	103·5
28	29·687	30·265	HZ.	B.	43·3	54·8	35·3	95·0
29	29·652	30·230	M.	C. to B.	34·2	56·8	34·0	103·2
30	29·335	29·906	B.	B. to C.R.	47·2	62·9	39·0	107·8
31	29·151	29·719	B.	C.B.	50·0	60·8	44·1	**111·2**
Extreme, Mean, or Sum.	**29·896** 28·536				40·9	**63·3**	29·9	**111·2**

NOTE.—Heavy type indicates maximum or in large quantities ;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Mar. 1	0·195	...	...	647	27·0	11·0	10·5	S.S.W.
2	...	8	25	462	19·2	4·0	*12·40*	W.
3	...	4	35	259	10·8	1·3	*12·5*	S.W.
4	...	5	50	537	22·4	7·0	*6·30*	N.W.
5	...	3	10	488	20·3	7·5	*10·25*	W.S.W.
6	0·135	1	55	**691**	**28·8**	**15·0**	*4·20*	N.W.
7	0·020	1	5	329	13·7	3·5	12·30	N.W.
8	0·050	...	25	393	16·4	3·0	6·20	S.S.W.
9	0·105	...	...	460	19·2	4·0	5·10	S.S.W.
10	0·030	5	15	432	18·0	3·0	*3·50*	W.S.W.
11	0·040	4	30	648	27·0	7·3	1·55	S.W.
12	0·050	2	30	488	20·3	3·5	6·25	W.S.W.
13	**0·340**	6	0	561	23·4	7·0	5·0	W.N.W.
14	...	5	30	288	12·0	1·4	1·40	W.
15	...	2	15	276	11·5	2·0	*3·50*	N.N.W.
16	...	5	10	240	10·0	...	...	...
17	...	...	...	129	5·4	...	...	...
18	...	3	55	134	5·6	...	...	...
19	...	...	...	203	8·5	...	...	...
20	..	...	...	161	6·7	...	...	...
21	...	...	45	227	9·5	...	...	...
22	...	...	...	208	8·7	...	...	...
23	...	3	40	226	9·4	...	...	...
24	...	5	55	246	10·2	0·5	*2·30*	E.S.E.
25	...	**10**	**20**	235	9·8	1·0	11·0	E.S.E.
26	...	9	25	163	6·8	...	...	...
27	...	7	20	140	5·9	...	...	...
28	...	8	25	181	7·5	...	...	...
29	...	6	10	129	5·4	...	...	...
30	0·010	6	30	220	9·2	5·5	*5·25*	E.S.E.
31	0·075	6	40	145	6·0	1·0	12·5	S.S.E.
Extreme, Mean, or Sum.	1·050	125	40	9,046	12·1	**15·0**	*4·20*	N.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
April 1	29·437	30·010	B.	B. to C.B.	53·9	63·3	41·5	118·3
2	29·346	29·917	B.	B.C.	50·6	64·7	43·0	115·4
3	29·267	29·837	B.	B.C.	52·8	59·9	44·0	110·2
4	29·499	30·073	B.Hz.	B.Hz.	45·7	62·0	42·0	112·3
5	**29·624**	30·201	B.Hz.	B.Hz.	44·1	57·2	40·5	100·0
6	29·480	30·054	O.	O.R.	42·7	50·5	39·0	69·4
7	29·426	29·999	O.	O.	41·9	49·2	41·0	70·2
8	29·348	29·919	O.M.	O. to C.B.	41·0	61·6	40·0	109·0
9	29·363	29·935	C.	B.C. to C.	50·3	57·5	43·3	106·8
10	29·480	30·053	C.B.	C.B.	52·6	66·5	43·6	107·5
11	29·353	29·925	C.	C.Th.	56·5	**70·4**	50·3	106·4
12	29·154	29·722	O.	C.	48·0	56·8	47·0	111·0
13	29·222	29·801	O.	C.B.	45·3	53·5	41·8	98·2
14	29·079	29·645	O.	C.R.	44·5	52·3	41·0	75·0
15	29.125	29·692	C.	C.B.R.	49·0	57·4	44·1	112·6
16	28·768	29·328	O.	R.	49·0	53·3	45·5	110·8
17	28·900	29·463	C.B.	C.B.	46·6	55·3	42·0	100·6
18	29·113	29·680	C.B.	C.B.R.	46·1	56·3	40·4	97·8
19	29·503	30·078	O.	O.	43·6	51·6	42·4	82·5
20	29·614	30·191	O.	C. to B.C.	40·5	52·6	37·0	95·2
21	29·497	30·071	B.C.	B.C. to B.	45·2	56·5	36·0	107·0
22	29·351	29·923	O.	C.	40·3	48·3	36·6	89·0
23	29·032	29·597	Hz.	B.C. to R.	43·9	51·0	36·3	108·0
24	28·993	29·557	R.	R.B.C.	46·7	51·9	41·6	107·8
25	29·039	29·604	C.	C.B.R.	44·2	55·8	42·0	111·0
26	29 053	29·619	C.B.	C.B.R.	44·5	54·6	42·3	111·0
27	29·047	29·612	B.C.	C.B.	49·2	56·9	40·5	115·5
28	29·347	29·918	O.	C.B.	49·4	53·0	44·6	95·5
29	29·520	30·090	Hz.	C.B.	51·8	63·0	42·5	**125·6**
30	29·505	30·080	R.	C.	51·4	54·7	47·2	75·6
Extreme, Mean, or Sum.	**29·624** 28·768				47·0	**70·4**	36·0	**125·6**

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Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
April 1	...	7	20	109	4·5	...	...	...
2	0·010	**10**	**20**	175	7·3	1·0	*9·20*	S.S.E.
3	0·005	7	25	184	7·7	1·0	*8·30*	E.N.E.
4	...	7	50	190	7·9	...	...	...
5	...	7	45	392	16·3	2·8	*5·20*	E.N.E.
6	0·070	...	...	**473**	**19·7**	2·5	7·10	E.N.E.
7	...	...	...	408	17·0	1·2	*8·15*	E.N.E.
8	...	4	20	156	6·1	...	...	...
9	...	4	10	267	11·1	1·6	10·35	S.S.W.
10	...	8	15	226	9·4	1·0	*12·25*	S.
11	0·360	5	50	232	9·7	3·4	*4·25*	S.E.
12	...	1	20	196	8·2	...	...	...
13	...	4	50	219	9·1	...	...	...
14	0·070	...	15	337	14·0	2·8	10·40	S.S.E.
15	0·045	5	20	294	12·3	3·0	11·55	S.
16	0·230	...	50	333	13·9	2·3	*3·30*	S.W.
17	...	3	5	174	7·2	0·6	*1·25*	S.S.E.
18	0·170	4	5	222	9·2	1·0	*3·40*	N.N.W.
19	...	...	40	290	12·1	0·5	8·40	N.E.
20	...	4	35	160	6·7	...	...	...
21	...	9	25	138	5·8	...	...	...
22	...	...	20	226	9·4	...	...	...
23	0·110	2	0	235	9·8	1·1	10·30	S.E.
24	0·120	3	5	425	17·7	**6·5**	*1·25*	S.S.W.
25	0·130	3	45	306	12·7	3·0	*2·35*	S.S.W.
26	0·135	3	40	268	11·2	2·5	*12·25*	S.S.W.
27	. .	4	35	222	9·2	2·0	*2·30*	S.
28	...	2	15	199	8·3	...	...	...
29	0·010	3	5	169	7·0	...	...	...
30	0·155	...	...	301	12·5	2·0	*5·20*	N.E.
Extreme, Mean, or Sum.	1·620	120	25	7,526	10·4	**6·5**	*1·25*	S.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
May 1	29·779	30·359	C.	C.B.	46·5	53·8	39·2	97·9
2	29·623	30·200	O.	C.R.	44·3	50·0	41·5	80·6
3	29·249	29·816	C.	C.	50·5	53·6	41·4	106·2
4	29·257	29·826	C.B.	C.B.	43·5	51·4	40·6	93·4
5	29·345	29·916	C.	B.C.	44·7	53·8	37·8	106·3
6	29·134	29·701	O.	C.B.	49·3	56·3	47·2	114·0
7	29·230	29·799	B.C.	B.C.	48·4	57·2	42·5	114·0
8	29·380	29·952	O.	O.	49·5	54·8	45·0	104·3
9	29·151	29·719	R.	R.	47·2	50·0	42·9	70·2
10	29·104	29·671	C.	C.B.R.	47·2	55·1	39·4	110·2
11	29·232	29·801	C.	B.C. to R.	49·3	53·8	40·9	95·0
12	29·429	30·002	C.B.	C.B.	48·3	53·7	44·2	109·4
13	29·534	30·109	C.B.	B.C.toC.toR.	48·8	59·2	40·0	**119·7**
14	29·335	29·906	O.	C.	50·2	59·6	44·6	112·0
15	29·315	29·886	C.	C.	54·2	62·3	46·8	90·4
16	29·361	29·933	O.	R.	48·5	54·1	46·7	73·9
17	29·603	30·180	O.	C.	46·9	54·5	45·6	86·9
18	29·660	30·237	O.	C. to B.C.	44·7	57·0	42·2	104·9
19	29·685	30·263	O.	C.B. to C.	42·4	47·5	40·8	100·0
20	29·423	29·996	C.B.	B.C. to C.B.	41·8	48·2	33·0	105·6
21	29·405	29·978	C.	C.B. to R.	41·5	50·5	32·8	104·0
22	29·524	30·099	C.B.	C.B.	42·8	52·0	34·5	105·5
23	29·679	30·257	O.	C.	43·6	50·6	39·0	66·3
24	**29·799**	30·379	B.	B.	49·6	60·8	40·4	109·1
25	29·583	30·159	B.	B. to B.C.	51·7	**63·0**	37·3	111·2
26	29·266	29·836	C.	C.B. Th. R.	44·7	50·2	39·1	102·2
27	29·211	29·780	C.	C.B.R.	42·3	50·4	40·5	106·2
28	28·999	29·563	C.	C.B.R.	42·3	49·6	35·6	107·0
29	29·003	29·568	O.	O.R.	43·3	51·9	38·0	97·9
30	29·131	29·698	O.	C.R.Th.	47·5	55·1	37·0	109·6
31	29·151	29·719	C.B.	C.B.R.&Th.	48·6	56·9	40·0	116·0
Extreme, Mean, or Sum.	**29·799** 28·999				46·6	**63·0**	32·8	**119·7**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
May 1	...	4	40	303	12·2	1·1	*8·15*	N.N.W.
2	0·050	...	25	243	10·1	0·6	*12·30*	W.N.W.
3	0·010	1	55	378	15·7	2·6	*3·0*	W.N.W.
4	0·060	2	25	**574**	**23·9**	**7·5**	10·50	N.W.
5	...	4	20	290	12·1	1·0	1·50	N.W.
6	0·020	4	30	346	14·4	2·0	9·35	S.W.
7	...	9	40	400	16·7	3·7	*4·40*	W.
8	...	...	20	383	16·0	2·5	11·25	S.W.
9	**0·415**	...	...	294	12·2	2·8	2·50	S.S.W.
10	0·025	4	50	345	14·4	2·0	8·25	S.S.W.
11	0·300	2	50	238	9·9	...	...	...
12	0·080	7	10	508	21·2	3·6	*5·35*	N.W.
13	0·010	7	5	226	9·4	1·0	*10·30*	S.
14	0·065	...	50	320	13·3	2·0	*12·20*	S.
15	...	1	30	312	13·0	1·3	*4·30*	E.
16	0·350	...	...	382	15·9	1·5	*8·25*	E.N.E.
17	0·025	...	...	427	17·8	2·5	*7·55*	E.N.E.
18	...	5	50	482	20·1	2·8	*10·40*	E.N.E.
19	...	2	30	439	18·3	4·6	6·10	E.N.E.
20	...	6	30	239	10·0	1·0	10·25	N.E.
21	0·045	6	15	203	8·5	1·2	*6·30*	N.N.E.
22	...	6	20	264	11·0	1·6	*4·20*	N.E.
23	...	...	...	439	18·3	3·5	*4·30*	E.N.E.
24	...	10	30	435	18·1	2·5	*4·5*	E.N.E.
25	...	**11**	**25**	344	13·3	2·5	*6·0*	N.N.W.
26	0·105	4	55	422	17·6	6·5	*3·40*	N.E.
27	0·035	2	35	435	18·9	3·5	2·25	N.
28	0·005	4	50	202	8·4	0·8	*12·50*	W.N.W.
29	0·080	1	5	117	4·9	...	...	...
30	0·185	3	10	193	8·0	1·0	*2·25*	W.
31	0·150	6	15	153	6·4	...	...	...
Extreme, Mean, or Sum.	2·015	124	40	10,354	13·9	**7·5**	10·50	N.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
June 1	29·310	29·881	C.B.	C.B. to C.	52·0	58·8	41·4	111·0
2	29·045	29·610	C.	C.	53·9	57·6	48·5	94·5
3	29·369	29·941	C.B.	C.B. to C.	55·5	61·0	49·6	111·8
4	29·240	29·809	R.	R. to C.	52·5	57·8	50·2	61·0
5	29·157	29·725	C.	C.R.	52·4	57·9	49·8	99·2
6	29·247	29·816	O.	C.	47·1	54·4	44·8	73·8
7	29·258	29·828	C.B.	C.B.	49·8	60·1	41 2	104·1
8	29·413	29·986	O.	C.	50·9	61·4	47·7	104·2
9	29·275	29·845	O.	C.	54·3	60·9	50·9	100·1
10	29·274	29·844	C.	C.R.	54·6	60·8	51·8	111·0
11	29·174	29·741	C.	C.B R.	50·0	54·1	46·0	112·7
12	29·327	29·898	C.	C.B.R.	52·1	61·3	45·0	113·4
13	29·424	29·997	C.	C.	51·0	57·0	42·3	80·9
14	29·577	30·153	C.B.	C.B.	57·4	66 0	47·8	118·6
15	29·539	30·114	O.	O. to R.	56·5	64·3	50·7	107·4
16	29·584	30·160	B.C.	B.C.	54·8	64·8	48·0	104·5
17	29·331	29·902	C.B.	C.B.R.	58·1	64·3	47·0	120·6
18	29·192	29·760	C.	C.R.	54·5	56·0	44·8	111·8
19	29·523	30·098	C.B.	C.B.	54·1	62·2	43 0	114·8
20	29·381	29·953	C.	C. to C.B.	57 3	65·2	51·8	116·4
21	29·597	30·174	Hz.	B.C. to B.	55·4	68·5	44·2	117·1
22	29·541	30·116	B.C.	C.B.	61·6	68·0	54·4	123·5
23	29·480	29·981	C.B.	C.B.	56·3	64·8	52·2	123·5
24	29·351	29·923	C.	B.C.	55 9	60·0	52·4	113·6
25	29·576	30·152	C.	C.	56·8	65·5	51·9	107·1
26	29·730	30·309	C.	C.	63·0	65·7	56·0	94·0
27	29·769	30·349	C.B.	B.C.	55·3	68·3	50·1	116·1
28	29.759	30·339	B.C.	B.C.	58·1	72·4	49·2	119·0
29	29·810	30·391	B.C.	B.C. to B.	54·7	74·0	53·8	119·7
30	**29·835**	30·416	B.	B.	65·2	**78·5**	52·2	**125·4**
Extreme, Mean, or Sum.	**29·835** 29·045				55·0	**78·5**	41·2	**125·4**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
June 1	...	4	45	201	8·4	...	...	...
2	0·180	...	25	416	17·3	**5·0**	*5·30*	W.S.W.
3	...	2	20	177	7·4	1·0	12·35	W.S.W.
4	**1·015**	...	...	232	9·7	1·0	7·10	E.S.E.
5	0·100	...	25	317	13·2	1·0	10·40	S.S.W.
6	0·110	...	10	387	16·1	2·0	*6·0*	N.E.
7	...	9	10	338	14 1	1·5	*1·30*	N.N.W.
8	0·010	...	50	160	6·6	...	...	...
9	0·035	...	30	145	6·0	...	...	...
10	0 060	...	5	267	11·1	2·2	*2·10*	S.W.
11	0·160	2	35	**436**	**18·2**	3·5	8·30	W.N.W.
12	0·045	4	25	381	15·9	2·0	*4·25*	N.W.
13	...	...	10	305	12·7	1·5	10·55	N.W.
14	...	7	15	251	14 6	1·0	*12·40*	W.N.W.
15	0·385	...	55	287	12·0	1·5	*7·50*	W.
16	...	11	0	145	6 0	...	...	...
17	0·005	4	20	318	13·2	3·0	*3·30*	S.W.
18	0·040	3	50	272	11·3	2·7	*6·40*	N.
19	...	8	20	290	12·1	1·3	*5·5*	S.W.
20	0·015	1	5	307	12 8	1·3	*6·25*	N.N.W.
21	...	10	10	193	8·0	...	...	...
22	...	4	50	269	11·2	1·1	*12·40*	S.W.
23	...	2	55	368	15·3	3·0	*2·10*	S.S.W.
24	...	6	35	324	13·5	2·0	4·0	W.
25	...	...	40	251	10·5	...	...	...
26	...	...	...	189	7·9	...	...	...
27	...	9	0	294	12·2	1·0	*2·0*	E.N.E.
28	...	10	20	292	12·2	1·0	*6·40*	E.
29	...	10	20	286	11·9	0·5	*6·0*	E.
30	...	**14**	**0**	278	11·6	1·5	*6·30*	E.
Extreme, Mean, or Sum.	2·160	131	25	8,376	11·6	**5·0**	*5·30*	W.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
July 1	**29·728**	30·307	B.	B.	67·0	80·6	53·2	125·2
2	29·554	30·130	C.	C. to C.B.	65·9	72·9	61·3	123·7
3	29·568	30·144	C.B.	C.B. to C.	60·2	63·4	55·8	105·4
4	29·593	30·169	C.B.	B.C.	60·6	71·8	48·3	127·8
5	29·581	30·157	B.	B.	64·3	75·9	51·5	123·6
6	29·427	30·000	C.B.	B.C.	67·0	**80·7**	54·7	**130·8**
7	29·392	29·964	C.B.	B.C.R.	59·4	67·4	54·0	119·8
8	29·451	30·025	C.B.	C.B. to C.	56·6	66·7	48·0	129·0
9	29·215	29·784	C.	C.B.	59·0	69·2	52·1	124·5
10	29·007	29·572	C.	C. to R.	58·0	62·3	52·0	105·5
11	28·789	29·349	C.	C. to R. & Th.B.	56·4	62·3	51·2	116·8
12	28·791	29·351	C.	C.B.R.Th.	54·7	65·3	49·2	123·3
13	29·026	29·591	C.B.	C.B.R.	55·7	65·8	51·0	125·3
14	29·089	29·655	C.B.	C.B.	55·9	68·3	47·9	126·0
15	29·274	29·844	O.	O.	53·6	58·3	53·2	90·0
16	29·274	29·844	R.	R.toC.B.toC.	55·0	67·2	50·0	117·7
17	29·179	29·747	C.	C.	56·0	61·8	54·0	110·3
18	29·044	29·609	C.	C.R.	53·1	60·1	51·1	114·2
19	29·180	29·748	O.	C.&R.toC.B.	55·6	63·0	51·9	117·0
20	29·324	29·895	B.C.	C.B.R.	57·6	64·8	51·6	121·6
21	29·247	29·817	C.	C.B.Th.R.	59·5	69·1	51·2	124·5
22	29·312	29·883	O.	C. to R.	59·4	62·8	50·5	104·0
23	29·291	29·861	O.	O.	54·0	59·5	52·0	76·7
24	29·459	30·033	R.	R.	56·6	58·8	55·1	76·7
25	29·372	29·944	C.	C.B.	61·3	72·9	57·0	126·0
26	29·347	29·918	C.B.	C.B.	59·5	67·8	50·6	124·5
27	29·382	29·954	B.C.	B.C.	60·1	72·6	53·0	129·3
28	29·532	30·107	C.	C.B. to C.	62·0	71·5	55·7	122·9
29	29·452	30·026	O.	C.	61·0	71·2	56·9	99·6
30	29·423	29·996	O.	O.	58·6	67·0	55·1	107·5
31	29·422	29·995	B.	B.C. to C.	65·4	74·5	55·0	123·7
Extreme, Mean, or Sum.	**29·728** 28·789				59·0	**80·7**	47·9	**130·8**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
July 1	...	12	30	304	12·7	1·5	*2·30*	E.S.E.
2	0·005	3	55	217	9·0	1·3	*2·55*	S.S.W.
3	...	2	10	340	14·2	1·8	7·35	N.W.
4	...	**12**	**50**	199	8·3	...	...	...
5	...	14	20	247	10·3	1·5	*1·35*	S.
6	...	8	20	302	12·6	3·5	*5·55*	S.
7	0·090	10	5	328	13·7	3·0	1·0	S.S.W.
8	...	4	55	288	12·0	1·4	11·30	W.S.W.
9	...	1	30	236	9·8	1·0	*12·25*	W.S.W.
10	0·475	1	0	147	6·1	...	...	...
11	0·255	3	55	260	10·8	...	...	...
12	0·075	4	35	265	11·0	...	...	...
13	0·020	3	45	259	10·8	...	...	...
14	0·050	6	0	198	8·2	...	...	...
15	0·010	...	...	264	11·0	2·0	10·35	N.W.
16	0·180	1	0	381	15·9	**5·3**	*5·10*	W.S.W.
17	0·010	...	45	390	16·2	4·0	*5·20*	W.
18	0·240	1	20	380	15·8	2·5	7·50	W.
19	0·120	1	10	286	11·9	1·0	*6·35*	N.W.
20	0·025	5	35	260	10·8	1·0	*3·15*	S.W.
21	0·195	3	55	137	5·7	1·0	6·0	W.
22	0·020	1	20	122	5·1	...	...	...
23	0·480	...	...	263	11·0	1·0	*3·5*	N.N.E.
24	0·035	...	...	**440**	**18·3**	3·4	*6·30*	E.N.E.
25	**1·070**	1	20	210	8·7	1·0	*4·10*	S.
26	...	3	50	163	6·8	...	...	...
27	...	10	15	158	6·6	...	...	...
28	0·010	3	25	126	5·3	...	...	...
29	...	...	35	284	11·8	1·5	*3·10*	E.N.E.
30	...	...	30	238	9·9	2·0	1·35	N.E.
31	...	7	30	168	7·0	...	...	...
Extreme, Mean, or Sum.	3·365	132	20	7,860	10·5	**5·3**	*5·10*	W.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at th

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hai

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Tempera-ture.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation Maxi
Aug. 1	29·245	29·814	O.	R. to C.	58·0	67·0	56·4	119·
2	29·033	29·598	O.	R. to C.B.	57·6	61·7	49·9	119·
3	28·973	29·537	O.	C.B.	54·2	64·0	46·5	120·
4	29·165	29·733	C.B.	B.C.toC.&R.	58·6	63·1	53·3	115·
5	29·293	29·863	B.C.	B.C. to C.	57·3	64·8	51·1	113·
6	29·200	29·769	R.	R. to C.B.	53·4	62·4	52·7	91·
7	29·284	29·854	B.C.	B.C.toC.&R.	56·3	63·0	45 5	112·
8	29·145	29·712	C.	Showers.	58·5	64·8	55·0	111·
9	29·164	29·732	C.B.	C.B.	57·9	64·2	52·0	**127·**
10	29·334	29·905	C.	C. toTh. & R.	56·1	61·3	53·2	116·
11	29·548	30·123	C.B.	C.	54·8	63·3	48·5	118·
12	29·494	30·068	C.	C. to R.	56·8	59·1	52·2	97·
13	29·359	29·931	C.B.	B.C.	56·2	62·9	53·0	116·
14	29·164	29·732	B.C.	B.C. to C.	63·2	69·5	54·7	114·
15	28·903	29·466	C.	C.B.	54·7	62·1	52·8	122·
16	29·175	29·743	O.	C. to C.B.	53·8	60·1	52·4	106·
17	29·504	30·079	O.	C.	53·3	58·7	47·5	89·
18	29·529	30·104	C.	C.B. to C.	55·4	59·3	51·0	105·
19	29·449	30·022	O.	C.R.	53·8	59·8	52·1	95·
20	29·299	29·869	C.	C.B.	52·5	59·1	48·8	113·
21	29·272	29·842	C.	C.R.	54·4	55·3	45·0	103·
22	29·240	29·809	C.	C. to B.C.	52·7	68·0	47·4	115·
23	29·284	29·854	O.R.	C. & R.	54·1	58·8	50·6	66·
24	29·493	30·067	O.	C.	51·7	58·0	50·0	75·
25	29·569	30·145	O.	O.	53·8	58·3	50·4	75·
26	29·355	29·927	O.M.	C. to B.C.	56·4	**69·8**	52·2	123
27	29·498	30·072	C.	C.	57·8	65·0	56·1	102·
28	29·667	30·245	O.	C.	55·2	63·3	54·1	97·
29	29·680	30·259	O.	C.	55·0	61·9	48·8	90·
30	**29·698**	30·276	B.HZ.	B.	55·8	69·2	47·8	110·
31	29·558	30·134	O.M.	C. to B.C.	53·3	66·1	50·5	102·
Extreme, Mean, or Sum.	**29·698** 28·903				55·6	**69·8**	45·0	**127·**

NOTE.—Heavy type indicates maximum or in large quantities

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Aug. 1	0·175	...	45	303	12·2	1·5	*2·35*	W.S.W.
2	0·220	1	25	287	12·0	7·0	11·5	W.
3	...	5	10	447	18·6	5·4	*3·40*	W.N.W.
4	0·035	4	0	304	12·7	1·4	*12·25*	S.W.
5	...	6	15	344	14·3	2·0	*1·25*	S.W.
6	0·235	2	0	216	9·0	1·0	1·20	S.S.W.
7	0·060	4	0	284	11·8	3·5	*10·30*	S.S.W.
8	0·210	2	0	345	14·4	2·8	*4·25*	W.S.W.
9	0·005	5	0	332	13·8	4·0	*12·35*	W.
10	0·165	1	10	316	13·2	2·0	*5·40*	N.N.W.
11	...	1	10	307	12·8	1·5	*3·50*	W.N.W.
12	0·100	...	5	316	13·2	2·3	9·5	W.
13	...	8	40	459	19·1	6·5	8·30	N.W.
14	...	2	0	489	20·4	**7·3**	*3·30*	W.S.W.
15	0·010	5	0	**526**	**21·9**	6·0	6·50	W.S.W.
16	0·010	2	30	382	15·9	3·6	*5·35*	N.W.
17	0·025	...	35	305	12·7	2·0	*3·40*	N.W.
18	...	2	10	330	13·7	1·6	11·0	N.W.
19	0·040	...	...	298	12·4	3·0	*10·30*	W.N.W.
20	...	5	30	406	16·9	5·6	11·25	N.W.
21	0·020	1	0	211	8·8	...	...	...
22	...	5	50	131	5·5	...	...	...
23	0·150	...	...	338	14·1	2·0	*5·35*	E.
24	0·045	...	...	331	13·8	2·0	2·35	E.N.E.
25	0·010	...	...	461	19·2	3·0	11·25	E.
26	**0·605**	4	0	225	9·4	1·5	12·20	E.N.E.
27	...	1	0	173	7·2	...	...	...
28	...	...	10	159	6·6	...	...	...
29	...	...	50	181	7·5	...	...	...
30	...	**9**	**0**	134	5·6	...	...	...
31	...	2	0	148	6·2	...	...	...
Extreme, Mean, or Sum.	2·120	83	15	9,488	12·7	**7·3**	*3·30*	W.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Tempera-ture.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radia-tion. Max.
Sept. 1	29·574	30·150	O.	C.B.	55·4	**65·7**	49·9	**109·**
2	29·532	30·107	C.B.Hz.	O.	55·8	62·8	52·1	99·0
3	29·419	29·992	O.	O.	49·4	57·0	48·8	92·0
4	29·514	30·089	B.C.	C.B.	53·0	56·4	41·8	89·8
5	29·537	30·112	C.B.	C.B.R. & Th.	51·2	56·9	43·0	96·0
6	29·551	30·127	C.B.	B. C. to R. & Th.	50·2	58·5	43·3	99·8
7	29·518	30·093	B.	C.B. to C.	52·5	55·5	45·5	103·8
8	29·340	29·911	B.	B.C.	49·1	55·5	46·2	97·8
9	29·655	30·233	B.C.	B.C.	53·2	61·0	47·2	108·1
10	29·861	30·443	B.C.Hz.	C.B.	48·0	60·8	42·7	95·4
11	29·765	30·345	B.	B.	54·0	63·6	45·1	103·2
12	29·803	30·384	C.	C.	55·6	61·5	52·6	96·1
13	29·856	30·438	C.	C.B.	49·0	59·0	44·4	97·0
14	29·821	30·402	C.	C.B.	54·8	62·5	49·0	92·8
15	29·840	30·421	B.Hz.	O.	53·2	61·3	50·7	95·8
16	29·816	30·397	O.	O.	54·1	56·0	50·8	73·0
17	29·790	30·370	O.	O.	50·5	54·1	49·5	62·8
18	29·652	30·230	O.	O.	53·4	58·1	50·2	70·0
19	29·558	30·134	O.	O.	53·1	58·9	51·6	78·0
20	29·565	30·140	O.	O.	53·3	59·5	52·8	84·3
21	29·462	30·036	O.	O.	48·0	55·5	46·2	90·0
22	29·328	29·899	O.	O.	52·0	57·0	50·0	77·3
23	29·213	29·782	R.	R.	50·9	55·2	50·0	58·0
24	29·272	29·842	R.	C.	52·2	60·4	52·0	96·3
25	29·180	29·748	R.	R.	50·8	53·0	49·5	57·0
26	29·271	29·841	C.	C.	50·8	56·2	48·4	101·0
27	29·612	30·189	C.	C.	47·2	54·1	46·0	81·3
28	29·768	30·348	B.C.	B.C. to C.	45·4	53·9	39·2	101·3
29	29·774	30·354	B.	B. to B.C.	46·0	56·1	37·5	98·0
30	**29·912**	30·495	B.	B.C. to C.	48·8	54·4	38·9	90·5
Extreme, Mean, or Sum.	**29·912** 29·180				51·3	**65·7**	37·5	**109·**

NOTE.—Heavy type indicates maximum or in large quantities

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Sept. 1	...	3	10	149	6·2	...	...	...
2	...	...	50	212	8·8	1·0	*9·25*	E.N.E.
3	0·080	...	25	308	12·8	1·5	4·30	E.N.E.
4	...	2	40	193	8·0	0·7	*3·30*	N.E.
5	0·060	1	35	212	8·8	0·8	*3·50*	N.E.
6	0·010	5	50	221	9·2	1·5	*4·35*	N.N.W.
7	...	2	15	308	12·8	2·0	10·0	W.N.W.
8	0·060	5	50	368	15·3	**2·6**	*2·25*	N.N.W.
9	...	6	40	**425**	**17·7**	2·5	*12·55*	N.N.E.
10	...	3	45	191	8·0	...	...	...
11	...	**9**	**25**	252	10·5	1·0	*8·55*	N.N.W.
12	...	1	5	278	11·6	0·8	*5·0*	E.N.E.
13	...	2	45	203	8·5	...	...	...
14	...	1	50	210	8·7	...	...	...
15	...	...	40	226	9·4	...	...	...
16	...	...	...	255	10·6	...	...	...
17	0·010	...	...	271	11·3	...	...	...
18	0·010	...	...	302	12·6	1·0	11·25	E.N.E.
19	...	...	...	135	5·6	...	...	...
20	...	...	15	188	7·8	...	...	...
21	...	...	...	187	7·8	...	...	...
22	...	...	10	277	11·5	0·7	*1·40*	E.
23	0·385	...	...	272	11·3	0·5	4·40	E.
24	0·110	...	40	329	13·7	1·0	11·50	E.N.E.
25	**0·970**	...	...	419	17·5	2·0	*1·25*	N.E.
26	...	1	10	245	10·2	1·0	9·55	N.N.E.
27	0·010	...	20	120	5·0	...	...	...
28	...	4	0	180	7·5	...	...	...
29	...	6	10	217	8·0	0·6	11·25	N.N.E.
30	...	4	20	198	8·2	...	...	...
Extreme, Mean, or Sum.	1·705	65	50	7,351	10·2	**2·6**	*2·25*	N.N.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Oct. 1	**29·938**	30·521	M.	C.	46·0	56·8	44·0	97·9
2	29·918	30·501	O.	O.	47·7	53·0	40·9	75·0
3	29·729	30·308	O.	O.	48·2	53·5	43·0	72·5
4	29·640	30·217	O.	O.	45·1	54·0	42·8	70·0
5	29·532	30·107	O.	C.R.	49·8	52·5	48·5	65·9
6	29·432	30·005	O.	R.	48·9	53·0	47·4	61·0
7	29·410	29·985	O.	O.	52·2	56·5	50·3	70·6
8	29·530	30·105	F.	O.	48·3	52·8	43·4	70·4
9	29·532	30·107	M.	O.	46·8	49·8	44·0	63·3
10	29·519	30·094	R.	R.	52·0	58·0	48·4	67·3
11	29·665	30·243	O.	Dark. O.	55·3	58·6	54·0	83·0
12	29·734	30·313	O.	C.	54·0	**60·0**	53·0	82·0
13	29·646	30·223	O.	C.	53·2	**60·0**	51·5	100·7
14	29·507	30·082	C.B.	C.B.	45·9	54·9	40·8	97·2
15	29·586	30·162	C.B.	C.B. to C.	40·7	47·0	37·0	85·0
16	29·627	30·204	B.C.	C.	41·2	47·1	38·8	72·0
17	29·554	30·130	O.	O.	43·3	47·0	38·7	57·0
18	29·235	29·804	O.	O.	40·1	47·3	36·4	87·8
19	29·111	29·678	O.	O.	40·0	46·0	38·0	62·0
20	28·971	29·535	C.	OR.	39·5	48·2	37·1	70·4
21	28·865	29·427	R.	R. to C.	41·0	44·7	35·5	60·3
22	29·264	29·834	B.Hz.	C.B.	35·1	46·6	31·5	75·0
23	29·393	29·964	C.B.	C. to R.	41·8	48·0	36·0	74·3
24	28·675	29·233	C.	R.	53·5	58·5	47·3	**103·**
25	28·440	28·993	C.	R.	50·4	54·0	47·9	99·4
26	28·890	29·352	B.C.	R.	49·0	54·0	46·0	87·1
27	28·609	29·166	R.	R.	47·3	52·0	44·9	84·1
28	29·050	29·615	O.	O.toC.B.toR.	43·3	50·8	42·4	91·4
29	28·971	29·535	B.C.	C.	44·3	50·6	40·5	91·4
30	29·152	29·720	C.B.	C. to R.	44·4	49 3	39·4	71·1
31	29·379	29·951	O.	R.	47·8	54·9	43·8	60·1
Extreme, Mean, or Sum.	**29·938** 28·440				46·3	**60·0**	31·5	**103·**

NOTE.—Heavy type indicates maximum or in large quantities

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Oct. 1	...	1	0	161	6·7	...	...	...
2	...	...	...	194	8·1	...	...	...
3	...	...	...	200	8·3	...	...	...
4	...	...	...	298	12·4	1·0	11·35	N.N.E.
5	0·030	...	...	279	11·6	...	...	...
6	0·085	...	...	254	10·6	...	...	...
7	...	...	...	113	4·7	...	...	...
8	...	...	...	84	3·5	...	...	...
9	...	...	...	128	5·3	...	...	...
10	0·335	...	...	230	9·6	1·0	4·20	S.S.W.
11	...	...	...	84	3·5	...	...	...
12	...	...	10	123	5·1	...	...	...
13	...	...	35	177	7·4	0·6	*8·35*	N.W.
14	0·100	3	15	394	16·4	2·0	*1·40*	N.N.E.
15	...	3	20	439	18·3	2·4	9·25	N.N.W.
16	...	1	0	324	13·5	1·2	2·20	N.N.W.
17	...	...	...	120	5·0	...	...	...
18	0·015	...	15	185	7·7	...	...	...
19	0·020	...	...	261	10·9	1·0	*6·20*	E.N.E.
20	0·020	...	...	267	11·1	1·2	*3·35*	E.
21	0·100	...	...	190	7·9	0·5	10·25	N.N.W.
22	...	**3**	**45**	235	9·8	0·5	*1·35*	E.
23	0·125	1	5	253	14·7	1·8	*9·25*	S.S.E.
24	0·420	1	40	570	23·7	7·4	*9·10*	S.W.
25	0·435	1	45	**583**	24·3	**9·7**	12·35	W.S.W.
26	0·400	1	45	339	14·1	2·1	12·35	W.
27	**0·540**	...	...	229	9·5	...	...	...
28	0·260	1	40	228	9·5	2·5	*9·5*	S.
29	0·125	1	55	429	17·9	3·0	*2·55*	S.W.
30	0·355	...	30	219	9·1	...	...	...
31	0·115	...	...	360	15·0	3·0	*9·35*	S.
Extreme, Mean, or Sum.	3·480	23	40	8,050	10·8	**9·7**	12·35	W.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Nov. 1	29·313	29·884	C.	C.	56·0	57·0	52·9	71·6
2	29·176	29·744	C.	C.B.	55·5	**60·0**	51·9	**97·9**
3	29·104	29·671	O.	C.R.	53·4	58·3	49·6	81·4
4	29·276	29·846	B.C.	C.B.	49·0	54·4	45·4	94·5
5	29·244	29·813	O.	C.B.	52·3	55·8	45·1	95·0
6	29·541	30·116	B.C.	B.C.	44·1	53·0	40·3	92·7
7	29·200	29·769	C.	R.	51·6	53·7	42·8	69·1
8	28·989	29·553	C.B.	C.B.	42·5	49·0	41·6	88·0
9	29·073	29·639	R.	O.	42·7	52·0	41·3	59·0
10	28·973	29·537	B.C.	B.C.R.	44·0	52·7	42·0	93·5
11	28·810	29·371	B.C.	B.C. to R.	41·3	49·0	38·3	91·3
12	28·571	29·127	R.	R.	42·0	44·1	37·9	46·0
13	29·093	29·659	B.C.	C.B.	40·3	46·8	39·0	91·8
14	28·455	29·009	C.	R.	46·4	50·4	40·0	53·4
15	28·686	29·244	O.	C.B.	40·6	48·1	37·4	84·0
16	29·198	29·766	B.	B.C.	39·6	49·7	38·2	83·0
17	29·463	30 037	B.C.	C.B.	42·8	52·5	39·4	79·0
18	29·508	30·083	O.	C.	44·0	46·5	41·4	61·7
19	29·628	30·203	O.	C.	44·8	50·0	42·8	73·5
20	29·518	30·094	O.	R.	50·8	51·9	42·8	55·6
21	29·829	30·410	C.	C.B.	37·8	46·7	36·9	85·0
22	29·702	30·281	C.	C.	42·7	49·0	37·4	65·1
23	29·718	30·297	O.	**F.**	45·2	48·3	44·4	54·6
24	29·797	30·377	O.	O.	40·2	47·0	38·0	61·3
25	29·774	30·354	M.	C.	45·5	46·3	38·5	68·0
26	29·782	30·362	O.	C.	37·6	40·9	36·0	41·5
27	29·826	30·407	O.	C.	40·4	41·8	37·0	44·8
28	29·820	30·401	O.	C.	40·2	45·8	37·0	52·9
29	29·717	30·296	O.	C.	44·7	48·8	41·5	67·3
30	**29·921**	30·504	B.	C.	34·8	44·9	33·2	68·2
Extreme, Mean, or Sum.	**29·921** 28·455				44·4	**60·0**	33·2	**97·9**

NOTE.—Heavy type indicates maximum or in large quantities;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Nov. 1	0·030	...	...	511	21·3	5·5	*2·10*	S.
2	0·020	3	20	371	15·5	4·0	2·30	S.S.W.
3	0·130	...	5	392	16·3	5·0	*12·25*	S.
4	...	3	5	349	14·5	2·5	*10·35*	S.S.W.
5	0·040	...	45	388	16·2	2·5	5·30	S.S.W.
6	...	6	45	262	10·9	...	...	...
7	0·220	...	...	414	17·2	4·0	10·25	S.
8	...	2	50	416	17·3	4·0	*12·20*	W.
9	0·060	...	...	292	12·2	2·0	11·20	S.S.W.
10	0·050	4	45	246	10·2	3·8	*2·5*	W.
11	0·110	5	25	333	13·9	4·0	*3·10*	W.S.W.
12	**0·765**	...	...	335	14·0	4·0	*10·10*	N.W.
13	0·040	5	0	**519**	**21.6**	9·0	*11·20*	S.S.W.
14	0·755	...	...	474	19·8	**17·0**	2·30	S.S.W.
15	...	2	45	276	11·5	3·2	*4·10*	S.W.
16	0·040	**7**	**0**	290	12·1	1·5	*6·25*	S.S.W.
17	...	3	45	347	14·5	3·0	11·50	S.
18	...	...	...	177	7·4	...	...	...
19	...	...	55	241	10·0	1·5	*11·25*	S.S.W.
20	0·220	...	...	440	18·3	5·0	10·50	S.S.W.
21	...	2	45	245	10·2	0·5	9·30	W.S.W.
22	...	...	20	251	10·5	1·0	2·40	S.S.W.
23	...	...	...	120	5·0	...	...	...
24	...	...	...	320	13·3	1·0	*8·30*	E.
25	...	...	...	282	11·7	0·8	12·0 noon	E.
26	...	...	...	366	15·3	1·4	*6·10*	E.N.E.
27	...	...	...	245	10·2	0·7	2·40	N.E.
28	...	...	...	188	7·8	...	...	...
29	...	...	...	254	10·6	2·0	*4·30*	N.N.W.
30	...	...	40	181	7·5	...	...	...
Extreme, Mean, or Sum.	2·480	50	10	9,525	13·2	**17·0**	2·30	S.S.W.

Ital. = P.M.

small type indicates minimum or in small quantities.

Daily Results of Meteorological Observations made at the

NOTE.—B. = Blue Sky. C. = Clouds. D. = Drizzling Rain. F. = Fog. H. = Hail.

DATE.	BAROMETER READINGS AT 9 A.M.		WEATHER.		TEMPERATURE.			
1894.	Corrected for Temperature.	Corrected to Sea Level.	At 9 a.m.	Generally during day.	At 9 a.m.	Highest.	Lowest.	Solar Radiation. Max.
Dec. 1	29·933	30·516	O.	C.	36·0	41·0	33·0	43·0
2	29·843	30·424	F.	C.	35·0	40·8	34·4	46·6
3	29·533	30·108	O.	O.	38·1	41·0	36·0	57·2
4	29·160	29·728	O.	O.	40·1	41·0	29·5	50·3
5	29·294	29·864	F.	F.	25·5	35·5	24·4	35·9
6	29·398	29·970	C.	C.	35·1	40·0	27·0	59·0
7	29·224	29·793	F.	O.R.	39·3	45·6	37·8	45·6
8	29·308	29·879	C.B.	C.	41·0	45·0	37·7	64·9
9	29·514	30·089	F.	C.	34·7	41·7	33·1	46·0
10	29·443	30·016	O.	O.	42·4	45·0	40·7	47·3
11	29·490	30·064	O.	O. to R.	44·4	48·2	43·5	51·4
12	29·435	30·008	C.B.	C.B.	44·4	48·0	43·0	63·0
13	28·473	30·047	C.B.	C.	47·3	**51·3**	43·0	61·3
14	29·551	30·127	O.	O. to R.	46·8	51·0	46·3	52·0
15	29·367	29·939	B.C.	B.C.	40·0	47·2	37·8	**81·5**
16	29·369	29·940	C.	C.	47·3	48·6	38·0	67·5
17	29·430	30·003	D.	C.	42·3	49·5	37·0	52·9
18	28·891	29·453	C.	C.B.	44·3	49·6	40·1	80·5
19	28·880	29·442	C.	C.B.	39·1	43·9	36·0	77·0
20	29·466	30·040	B.C.	B.C.	38·5	43·7	34·0	65·2
21	29·493	30·067	O.	O.	37·8	47·4	33·0	50·7
22	28·671	29·228	B.C.	C.	43·2	49·5	39·0	70·8
23	29·616	30·193	C.	C. to R.	37·3	42·0	36·4	55·0
24	29·503	30·078	M.	C.	45·6	49·0	41·5	55·7
25	29·890	30·472	C.	C.	43·9	47·7	43·5	53·0
26	29·944	30·527	C.	O.D.	43·5	47·3	40·0	55·0
27	**30·048**	30·633	B.	C.	37·0	42·9	35·0	66·0
28	29·855	30·437	C.	C.	38·0	46·0	34·3	49·6
29	28·759	29·319	C.B.	C.B.toTh.&S.	36·8	47·6	32·0	75·5
30	28·793	29·353	B.C.	B.C.	31·0	34·5	29·0	74·0
31	29·124	29·691	C.	...	29·8	32·9	25·6	60·9
Extreme, Mean, or Sum.	**30·048** 28·671				39·5	**51·3**	24·4	**81·5**

NOTE.—Heavy type indicates maximum or in large quantities ;

Birmingham and Midland Institute Observatory, Edgbaston.

Hz. = Hazy. M. = Mist. O. = Overcast. R. = Rain. S. = Snow. Th. = Thunder.

DATE.	RAIN.	SUNSHINE.		HORIZONTAL MOTION OF THE AIR.		EXTREME PRESSURE OF THE WIND ON THE SQUARE FOOT.		
1894.	Inches.	Hours.	Minutes.	Miles.	Mean Hourly.	Amount, pounds.	Time, hours.	Direction.
Dec. 1	...	...	...	165	6·9	...	...	...
2	...	...	...	155	6·5	0·5	*7·35*	S.E.
3	...	...	...	324	13·5	1·0	*5·30*	E.N.E.
4	...	...	...	212	8·8	0·6	3·45	E.N.E.
5	...	...	...	71	3·0	...	...	...
6	0·030	...	...	207	8·6	...	...	...
7	0·055	...	...	245	10·2	...	...	...
8	0·020	...	30	261	10·9	1·5	11·30	N.N.W.
9	...	...	...	290	12·1	2·5	*10·50*	S.
10	0·010	...	...	345	14·4	1·2	1·25	S.
11	0·160	...	...	344	14·3	1·6	*2·25*	S.
12	...	2	10	318	13·2	2·5	*10·25*	S.S.W.
13	...	...	...	525	21·9	7·5	10·35	S.S.W.
14	**0·365**	...	...	198	8·2	...	...	...
15	0·045	**5**	**20**	460	19·2	6·5	3·10	W.
16	0·130	...	...	363	15·1	4·8	7·35	W.N.W.
17	0·040	...	...	284	11·8	1·1	*12·25*	S.S.W.
18	0·090	2	50	598	24·9	6·0	*8·30*	W.
19	0·100	2	0	609	25·4	8·0	*12·20*	N.W.
20	...	3	5	441	18·3	4·0	12·50	N.N.W.
21	0·025	...	...	316	13·2	4·0	*11·55*	S.W.
22	0·240	...	55	**922**	**38·4**	**22·0**	11·50	W.
23	0·290	...	...	355	14·8	3·0	2·0	W.
24	...	...	...	180	7·5	...	...	...
25	...	...	...	159	6·6	...	...	...
26	0·030	...	...	280	11·7	1·0	*8·0*	N.N.W.
27	...	...	40	374	15·6	2·5	*12·15*	N.W.
28	...	...	...	506	21·1	18·0	*11·55*	W.N.W.
29	*0·250*	2	35	767	32·0	15·0	11·55	W.N.W.
30	...	3	10	542	22·6	3·0	11·50	N.W.
31	...	2	20	546	22·7	4·5	10·35	N.N.W.
Extreme, Mean, or Sum.	1·880 Ital. = Snow melted.	25	35	11,362	15·3	**22·0**	11·50 Ital. = P.M.	W.

small type indicates minimum or in small quantities.

EDGBASTON METEOROLOGICAL OBSERVATORY.

Comparison of Maxima, Minima, and Means for each month of 1893, with the Average for the same month for the past Six Years.

The Large Type is for 1893. The Small Type underneath, the corresponding figure for the past Six Years.

DATE.	BAROMETER.						TEMPERATURE.							SUNSHINE.	RAIN.	WIND.			DATE.
1893.	Mean of 9 a.m. Readings.	Mean corrected to Sea Level.	Highest.	Date of Highest Reading.	Lowest.	Date of Lowest Reading.	Mean 9 a.m. Readings.	Maximum.	Date of Maximum.	Minimum.	Date of Minimum.	Solar Radiation Maximum.	Date of Solar Radiation Max.	Total Hours and Minutes.	Total Inches.	Total Velocity in Miles.	Extreme Pressure in lbs. per sq. ft.	Date of Extreme Pressure.	1893.
														H. M.					
JANUARY, 1893 ...	29·457	30·031	29·815	19th	28·780	29th	34°·4	50°·6	31st	15°·0	4th	86°.6	31st	30—20	1·750	10377	5·0	18th	JANUARY, 1893.
Do. Past 6 Years	29·438	30·011	30·120	3rd, 1889	28·004	23rd, 1890	36°·8	58°·0	10th, 1888	14°·0	18th, 1891	86°·0	10th, 1888	41—21	1·477	9787	20·0	26th, 1888	Do. Past 6 Years.
FEBRUARY, 1893 ...	29·062	29·627	29·765	5th	28·199	21st	38°·3	56°·6	19th	28°·0	23rd	96°·6	19th	56—25	2·565	10160	15·0	10th	FEBRUARY, 1893.
Do. Past 6 Years	29·515	30·090	30·126	7th, 1887	28·624	18th, 1892	36°·7	61°.9	28th, 1891	15°·6	17th, 1892	97°·8	18th, 1889	50—25	0·833	9232	16·0	3rd, 1889	Do. Past 6 Years.
MARCH, 1893	29·520	30·095	29·846	19th	28·916	1st	43°·4	64°·8	29th	25°·6	18th	111°·2	29th	186—20	0·505	9156	8·2	17th	MARCH, 1893.
Do. Past 6 Years	29·291	29 860	30·041	30th, 1892	28·113	11th, 1888	38°·5	62°·0	2nd, 1891	21°·3	4th, 1890	107°·8	19th, 1892	75—58	1·661	10249	19·0	23rd, 1887	Do. Past 6 Years.
APRIL, 1893	29·602	30·179	30·015	8th	29·358	19th	47°·9	79°·0	20th	32°·3	13th	125°·7	21st	212— 0	0·330	7506	6·0	29th	APRIL, 1893.
Do. Past 6 Years	29·312	29·883	30·080	17th, 1887	28 533	4th, 1889	43°·2	68°·6	5th, 1892	27°·0	14th, 1892	118°·0	22nd, 1892	98—58	1·721	9354	12·0	1st, 1887	Do. Past 6 Years.
MAY, 1893	29·485	30·060	29·830	6th	28·985	18th	54°·1	74°·8	5th	39°·2	6th	125°·0	5th	179—55	2·085	8579	7·5	25th	MAY, 1893.
Do. Past 6 Years	29·252	29·821	29·890	11th, 1888	28·656	1st, 1888	51°·3	77°·4	28th, 1892	31°·0	17th, 1891	132°·3	31st, 1892	128—25	2·345	9399	18·0	20th, 1887	Do. Past 6 Years.
JUNE, 1893	29·437	30·008	29·804	10th	28·756	23rd	57°·7	82°·8	16th	45°·4	7th	128°·8	18th	159—15	1·080	7418	6·5	28th	JUNE, 1893.
Do. Past 6 Years	29·452	30·025	29·870	30th, 1887	28·663	30th, 1890	57°·5	79°·0	10th, 1892	38°·3	1st, 1890	131°·8	10th, 1892	146—42	2·077	8112	6·0	2nd, 1892	Do. Past 6 Years.
JULY, 1893	29·326	29·896	29·685	28th	28·947	20th	60°·3	83°·7	7th	48°·1	31st	138°·0	2nd	130—35	1·645	8539	5·0	9th	JULY, 1893.
Do. Past 6 Years	29·372	29·943	29·850	1st, 1889	28·717	1st, 1890	58°·4	84°·6	4th, 1887	39°.5	11th, 1888	132°·1	5th, 1887	118—52	2·430	8935	11·0	19th, 1892	Do. Past 6 Years.
AUGUST, 1893 ...	29·441	30·014	29·751	29th	28·943	21st	62°·2	85°·6	18th	44°·0	27th	131°·7	18th	192—55	2·255	8915	6·5	22nd	AUGUST, 1893.
Do. Past 6 Years	29·307	29·878	29·796	3rd, 1887	28·636	20th, 1889	58°·1	82°·4	7th, 1887	41°·2	14th, 1887	128°·0	7th, 1887	127—57	3·268	8659	12·0	26th, 1891	Do. Past 6 Years.
SEPTEMBER, 1893 ...	29·286	29·856	29·771	12th	28·655	30th	54°·3	73°·8	6th	39°·0	20th	127°·9	5th	128—40	1·725	8588	5·8	29th	SEPTEMBER, 1893.
Do. Past 6 Years	29·445	30·018	29·918	24th, 1887	28·494	2nd, 1887	54°·8	80°·5	11th, 1891	33°·0	29th, 1887	124°·6	14th, 1891	109—51	1·924	8331	12·0	1st, 1891	Do. Past 6 Years.
OCTOBER, 1893 ...	29·302	29·873	29·861	23rd	28·548	4th	47°·9	64°·7	21st	29°·0	31st	112°·0	16th	97—30	2·450	8732	7·5	28th	OCTOBER, 1893.
Do. Past 6 Years	29·301	29·872	30·096	31st, 1891	28·509	22nd. 1891	46°·3	65°·6	13th, 1890	27°·9	28th, 1890	109°·7	6th, 1890	79—33	2·564	9278	17·0	7th, 1889	Do. Past 6 Years.
NOVEMBER, 1893 ...	29·411	29·984	29·896	21st	28·472	17th	39°·1	57°·7	3rd	25°·9	18th	92°·0	3rd	29—50	1·385	11571	13·0	18th	NOVEMBER, 1893.
Do. Past 6 Years	29·300	29·871	30·069	5th, 1891	27·813	11th, 1891	42°·5	61°·6	9th, 1889	23°·5	27th, 1890	95°·1	8th, 1891	38—47	2·496	9229	19·0	24th, 1888	Do. Past 6 Years.
DECEMBER, 1893 ...	29·353	29·925	30·133	30th	28·208	20th	38°·6	51°·3	13th	22°·0	1st	78°·5	16th	45—25	3·025	10877	14·0	8th	DECEMBER, 1893.
Do. Past 6 Years	20·401	29·974	30·040	21st, 1891	28·382	13th, 1891	36°·4	55°·4	6th, 1888	14°·5	22nd, 1890	86°·0	5th, 1891	33—11	1·893	9069	24·0	10th, 1891	Do. Past 6 Years.
THE YEAR 1893 ...	29·390	29·962	30·133	30th Dec.	28·199	21st Feb.	48°·2	85°·6	18th Aug.	15°·0	4th Jan.	138°·0	2nd July	1449—10	20·800	110417	15·0	10th Feb.	THE YEAR 1893.
THE PAST 6 YEARS ...	29·365	29·930	30·126	Feb. 7th, 1887	27·813	Nov. 11th, 1891	46°·6	84°·6	July 4th, 1887	14°·0	Jan. 18th, 1891	132°·3	May 31st, 1892	1050—18	24·703	109635	24·0	Dec. 10th, 1891	THE PAST 6 YEARS.

EDGBASTON METEOROLOGICAL OBSERVATORY.

Comparison of Maxima, Minima, and Means for each month of 1894, with the Average for the same month for the past Seven Years.

The Large Type is for 1894. The Small Type underneath, the corresponding figure for the past Seven Years.

DATE.	BAROMETER.						TEMPERATURE.							SUNSHINE.	RAIN.	WIND.			DATE.
1894.	Mean of 9 a.m. Readings.	Mean corrected to Sea Level.	Highest.	Date of Highest Reading.	Lowest.	Date of Lowest Reading.	Mean 9 a.m. Readings.	Maximum.	Date of Maximum.	Minimum.	Date of Minimum.	Solar Radiation Maximum.	Date of Solar Radiation Max.	Total Hours and Minutes.	Total Inches.	Total Velocity in Miles.	Extreme Pressure in lbs. per sq. ft.	Date of Extreme Pressure.	1894.
														H. M.					
JANUARY, 1894 ...	29·242	29·811	30·002	3rd	28·741	31st	36°·0	53°·6	11th	10°·8	5th	86°·0	30th	44—40	1·610	11823	12·0	27th	JANUARY, 1894.
Do. Past 7 Years	29·441	30·014	30·120	3rd, 1889	28·004	23rd, 1890	36°·5	58°·0	10th, 1888	14°·0	18th, 1891	86°·6	31st, 1893	39—47	1·516	9871	20·0	26th, 1888	Do. Past 7 Years.
FEBRUARY, 1894 ...	29·402	29·975	29·926	19th	28·838	12th	38°·5	54°·4	7th	21°·7	21st	98°·2	4th & 27th	65—50	2·055	11749	27·5	11th	FEBRUARY, 1894.
Do. Past 7 Years	29·450	30·023	30·126	7th, 1887	28·199	21st, 1893	36°·9	61°.9	28th, 1891	15°·6	17th, 1892	97°·8	18th, 1889	51—16	1·080	9365	16·0	3rd, 1889	Do. Past 7 Years.
MARCH, 1894	29·363	29·934	29·896	23rd	28·536	13th	40°·9	63°·3	26th	29°·9	17th	111°·2	31st	125—40	1·050	9946	15·0	6th	MARCH, 1894.
Do. Past 7 Years	29·324	29·895	30·041	30th, 1892	28·133	11th, 1888	39°·2	64°·8	29th, 1893	21°·3	4th, 1890	101°·2	29th, 1893	91—44	1·496	10093	19·0	23rd, 1887	Do. Past 7 Years.
APRIL, 1894	29·282	29·852	29·624	5th	28·768	16th	47°·0	70°·4	11th	36°·0	21st	125°·6	29th	120—25	1·620	7526	6·5	24th	APRIL, 1894.
Do. Past 7 Years	29·354	29·926	30·080	17th, 1887	28·533	4th, 1889	43°·9	79°·0	20th, 1893	27°·0	14th, 1892	125°·7	21st, 1893	115— 7	1·522	9090	12·0	1st, 1887	Do. Past 7 Years.
MAY, 1894	29·373	29·945	29·799	24th	28·999	28th	46°·6	63°·0	25th	32°·8	21st	119°·7	13th	124—40	2·015	10354	7·5	4th	MAY, 1894.
Do. Past 7 Years	29·296	29·866	29·890	11th, 1888	28·656	1st, 1888	51°·7	77°·4	28th, 1892	31°·0	17th, 1891	132°·3	31st, 1892	135—12	2·306	9280	18·0	20th, 1887	Do. Past 7 Years.
JUNE, 1894	29·430	30·003	29·835	30th	29·045	2nd	55°·0	78°·5	30th	41°·2	7th	125°·4	30th	131—25	2·160	8376	5·0	2nd	JUNE, 1894.
Do. Past 7 Years	29·450	30·023	29·870	30th, 1887	28·663	30th, 1890	57°·5	82°·8	16th, 1893	38°·3	1st, 1890	131°·8	10th, 1892	148—30	1·935	8013	6·5	28th, 1893	Do. Past 7 Years.
JULY, 1894	29·313	29·884	29·728	1st	28·789	11th	59°·0	80°·7	6th	47°·9	14th	130°·3	6th	132—20	3·365	7860	5·3	16th	JULY, 1894.
Do. Past 7 Years	29·326	29·897	29·850	1st, 1889	28·717	1st, 1890	58°·7	84°·6	4th, 1887	39°·5	11th, 1888	138°·0	2nd, 1893	120—32	2·318	8878	11·0	19th, 1892	Do. Past 7 Years.
AUGUST, 1894 ...	29·341	29·912	29·698	30th	28·903	15th	55°·6	69°·8	26th	45°·0	21st	127°·0	9th	83—15	2·120	9488	7·3	14th	AUGUST, 1894.
Do. Past 7 Years	29·326	29·897	29·796	3rd, 1887	28·636	20th, 1889	58°·7	85°·6	18th, 1893	41°·2	14th, 1887	131°·7	18th, 1893	137—14	3·123	9696	12·0	26th, 1891	Do. Past 7 Years.
SEPTEMBER, 1894 ...	29·591	30·166	29·912	30th	29·180	25th	51°·3	65°·7	1st	37°·5	29th	109°·0	1st	65—50	1·705	7351	2·6	8th	SEPTEMBER, 1894.
Do. Past 7 Years	29·422	29·995	29·918	24th, 1887	28·494	2nd, 1887	54°·7	80°·5	11th, 1891	33°·0	29th, 1887	127°·9	5th, 1893	112—32	1·896	8368	12·0	1st, 1891	Do. Past 7 Years.
OCTOBER, 1894 ...	29·339	29·910	29·938	1st	28·440	25th	46°·3	60°·0	12th & 13th	31°·5	22nd	103°·0	24th	23—40	3·480	8050	9·7	25th	OCTOBER, 1894.
Do. Past 7 Years	29·301	29·872	30·096	31st, 1891	28·509	22nd, 1891	46°·5	65°·6	13th, 1890	27°·9	28th, 1890	112°·0	16th, 1893	82— 7	2·548	9200	17·0	7th, 1889	Do. Past 7 Years.
NOVEMBER, 1894 ...	29·357	29·929	29·921	30th	28·455	14th	44°·4	60°·0	2nd	33°·2	30th	97°·9	2nd	50—10	2·480	9525	17·0	14th	NOVEMBER, 1894.
Do. Past 7 Years	29·316	29·887	30·069	5th, 1891	27·813	11th, 1891	42°·0	61°·6	9th, 1889	23°·5	27th, 1890	95°·1	8th, 1889	37—30	2·337	9564	19·0	24th, 1888	Do. Past 7 Years.
DECEMBER, 1894 ...	29·412	29·965	30·048	27th	28·671	22nd	39°·5	51°·3	13th	24°·4	5th	81°·5	15th	25—35	1·880	11362	22·0	22nd	DECEMBER, 1894.
Do. Past 7 Years	29·395	29·966	30·133	30th, 1893	28·208	20th, 1893	36°·7	55°·4	6th, 1888	14°·5	22nd, 1890	86°·0	5th, 1891	34—56	2·054	9327	24·0	10th, 1891	Do. Past 7 Years.
THE YEAR 1894 ...	29·354	29·926	30·048	27th Dec.	28·440	25th Oct.	47°·3	80°·7	6th July	10°·8	5th Jan.	130°·3	6th July	993—30	25·540	113410	27·5	11th Feb.	THE YEAR 1894.
THE PAST 7 YEARS ...	29·369	29·940	30·133	Dec. 30th, 1893	27·813	Nov. 11th, 1891	46°·8	85°·6	Aug. 18th, 1893	14°·0	Jan. 18th, 1891	138°·0	July 2nd, 1893	1107—17	24·145	109747	24·0	Dec. 10th, 1891	THE PAST 7 YEARS.

METEOROLOGICAL READINGS EDGBASTON OBSERVATORY For six months ending DECEMBER 1893

JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

BAROMETER

WIND

TEMPERATURE

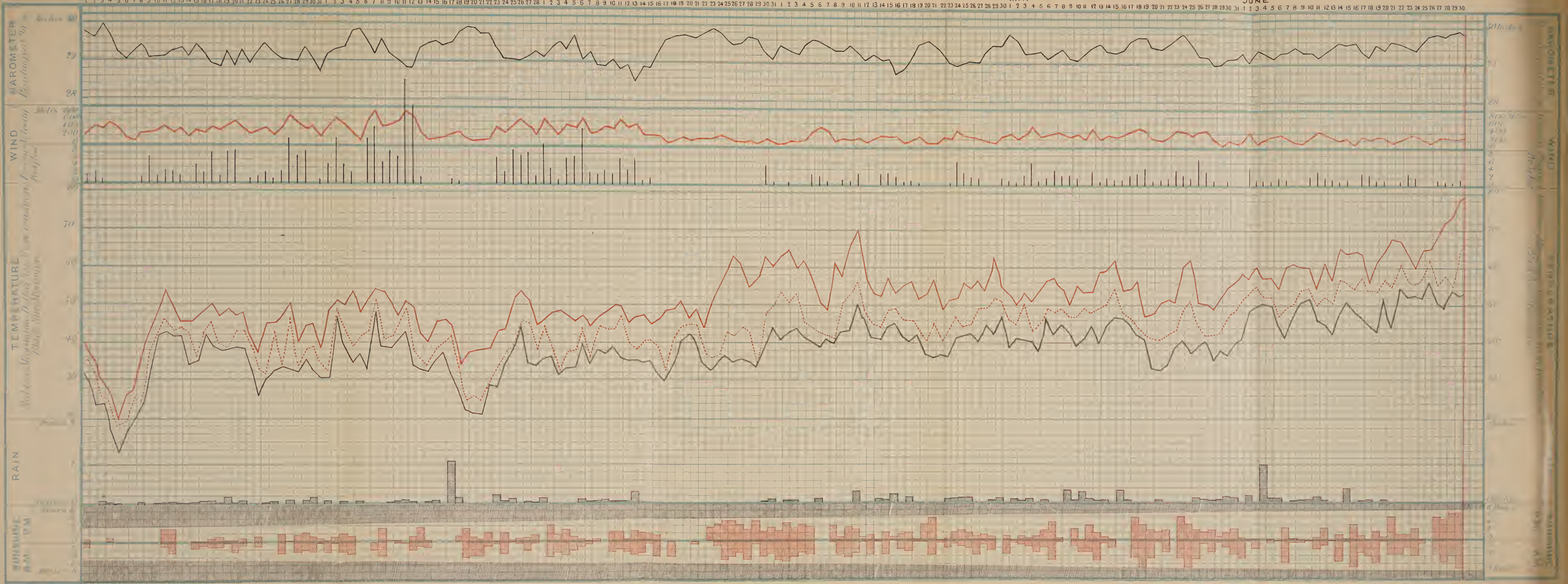
RAIN

SUNSHINE

Robert Burbeck & Sons Lith. Birmingham.

Melted Snow *

METEOROLOGICAL READINGS EDGBASTON OBSERVATORY For SIX MONTHS ENDING JUNE 1894



* MELTED SNOW

Robert Birbeck & Sons Lith. Birmingham

METEOROLOGICAL READINGS EDGBASTON OBSERVATORY For six months ending DECEMBER 1894

JULY 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
AUGUST 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
SEPTEMBER 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
OCTOBER 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
NOVEMBER 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DECEMBER 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Inches 30 29 28

Miles 800 600 400 200 0

8 6 4 2 0

80 70 60 50 40 30 20

Inches 2 1 0

Hours 8 6 4 2 0 2 4 Hours

30 Inches 29 28

800 Miles 600 400 200 0

8 6 4 2 0

80 70 60 50 40 30

2 Inches 1 0

8 Hours 6 4 2 0 2 4 Hours

BAROMETER Readings taken at 9 a.m. Monday to Friday Inclusive

WIND Miles passed By Wind

TEMPERATURE Maximum Minimum Black Bulb in vacuo readings

RAIN

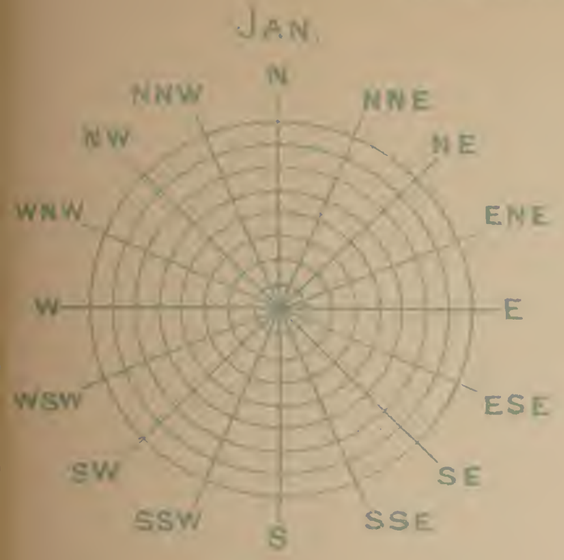
SUNSHINE AM PM

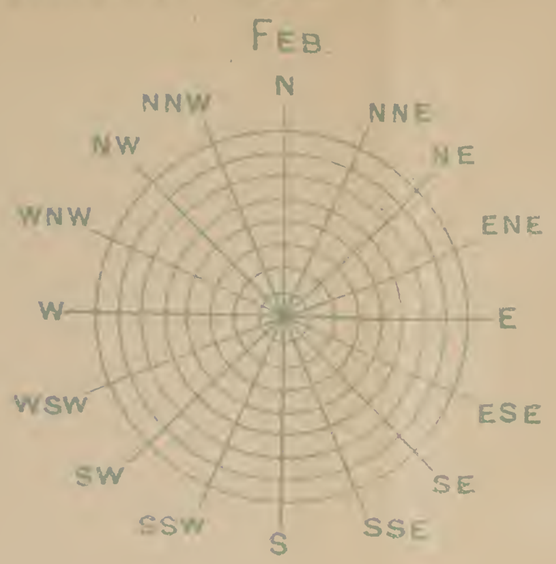
Robert Barbeck & Sons 15th Birmingham

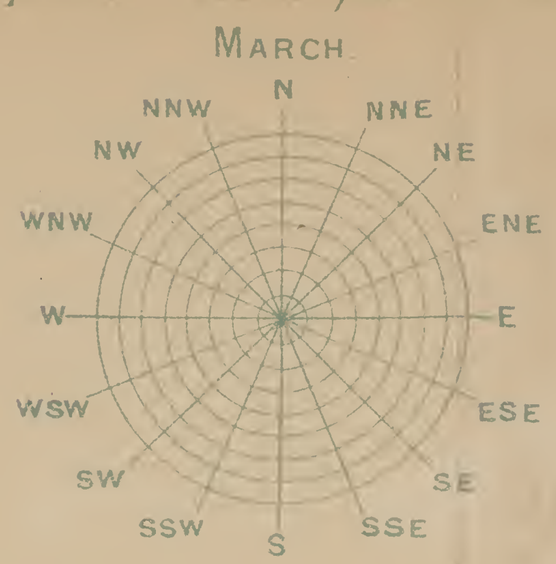
MELTED SNOW *

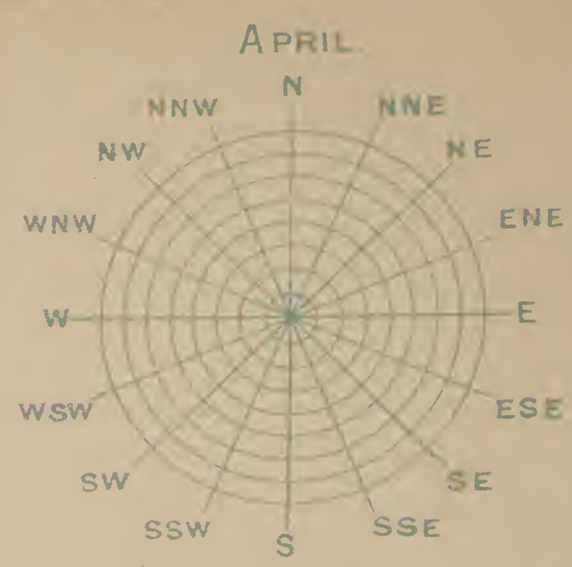
METEOROLOGICAL READINGS. EDGBASTON OBSERVATORY.

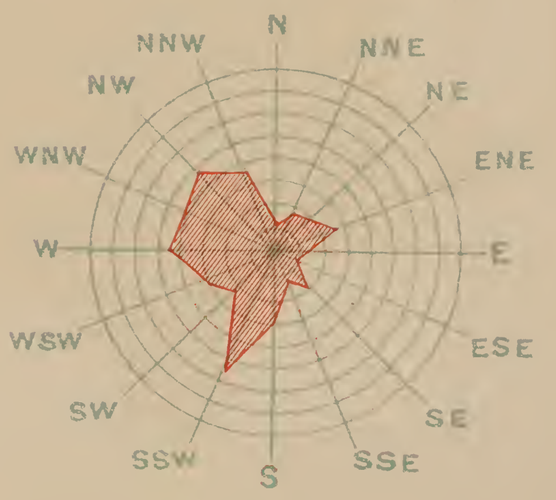
Horizontal Motion of the Air referred to 16 points of the Compass for the Year 1893

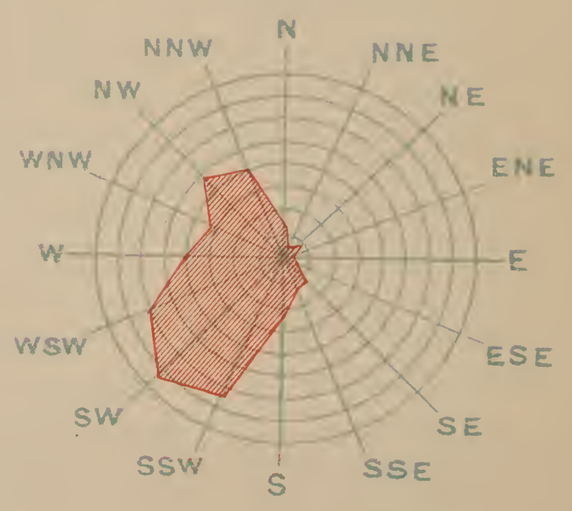


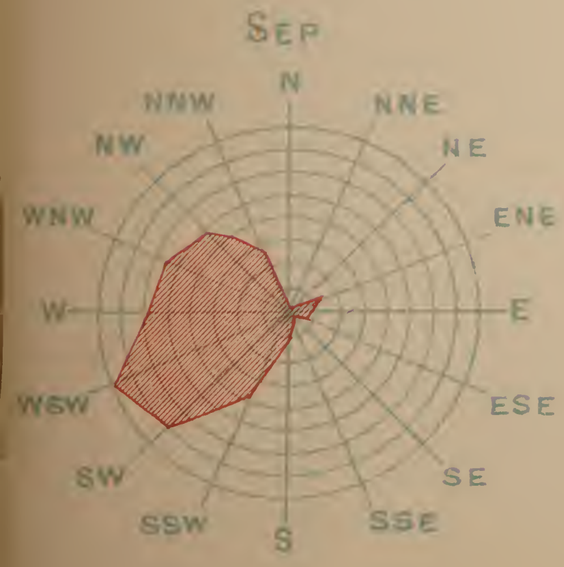


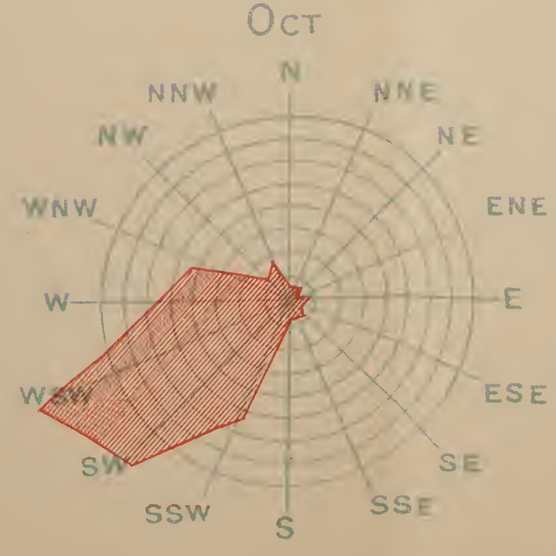


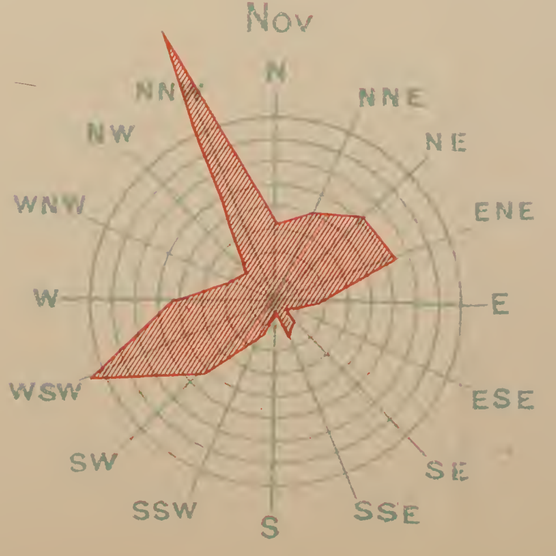


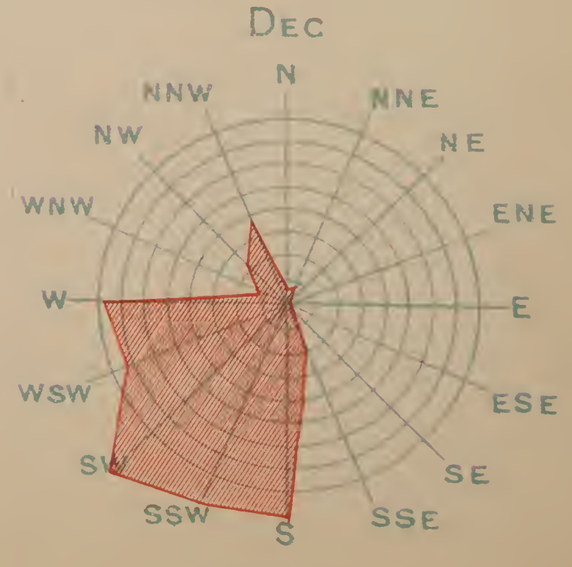










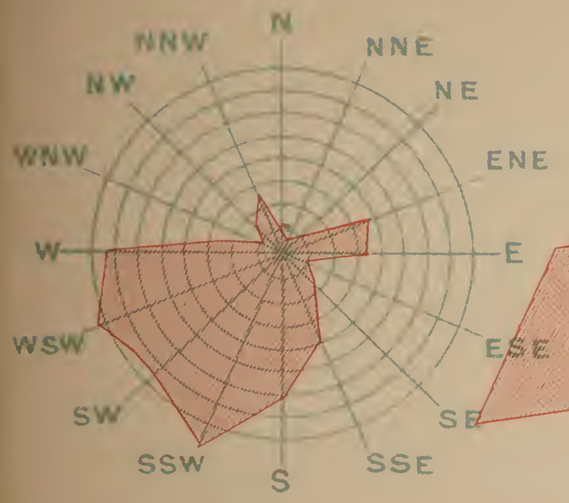


The Centre being Zero, each Concentric Circle represents 200 Miles

METEOROLOGICAL READINGS. EDGBASTON OBSERVATORY.

Horizontal Motion of the Air referred to 16 points of the Compass for the Year 1894

JAN.



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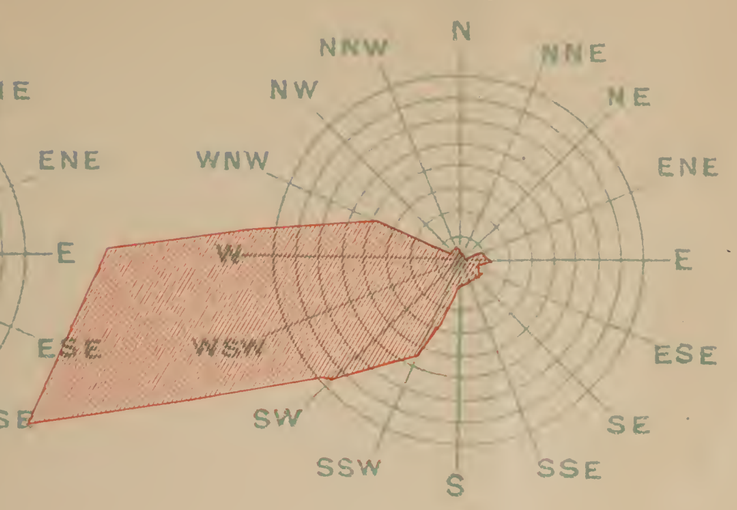

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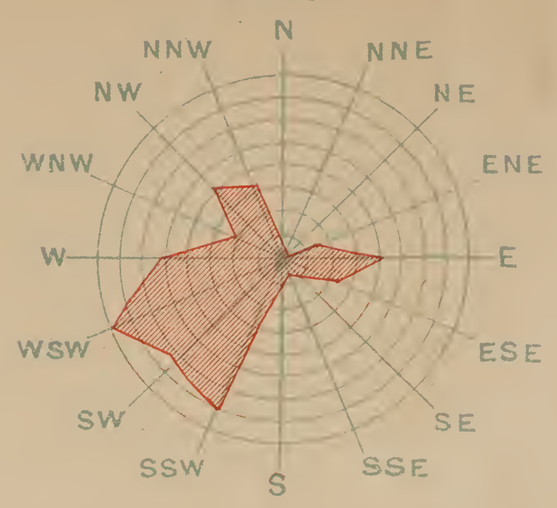

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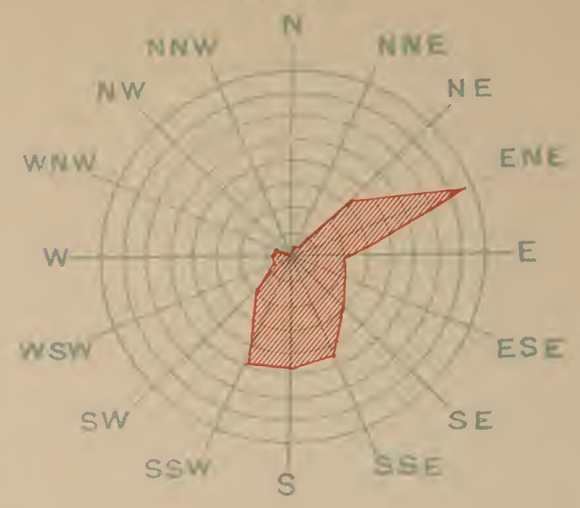

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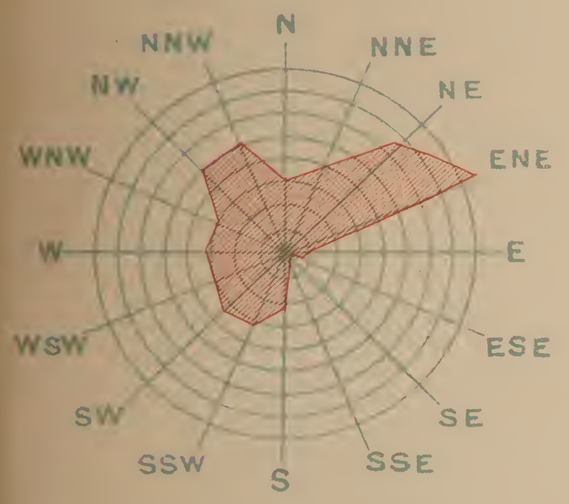

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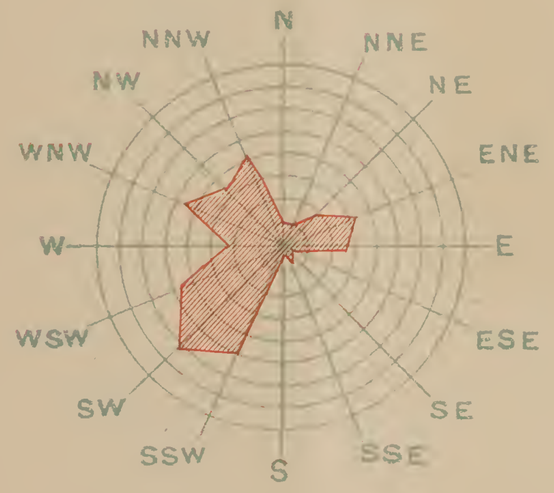

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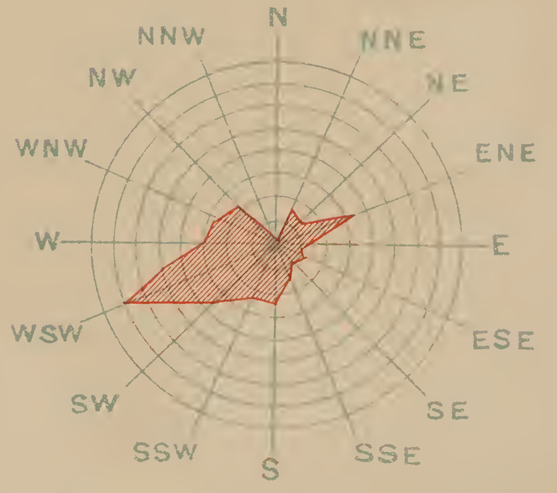

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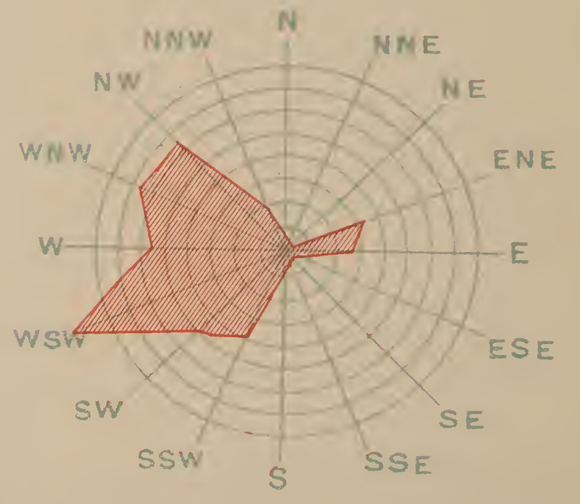

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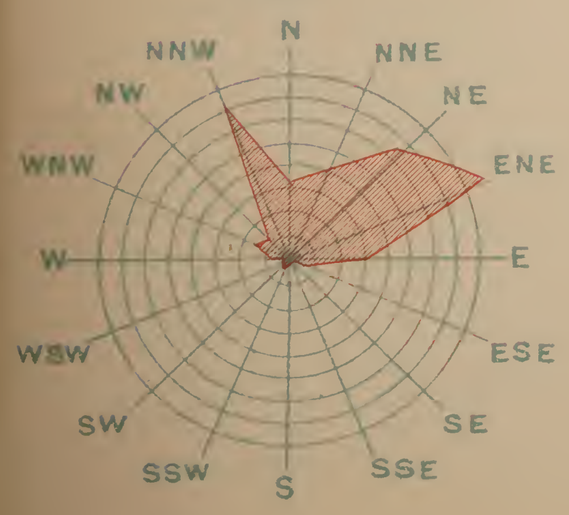

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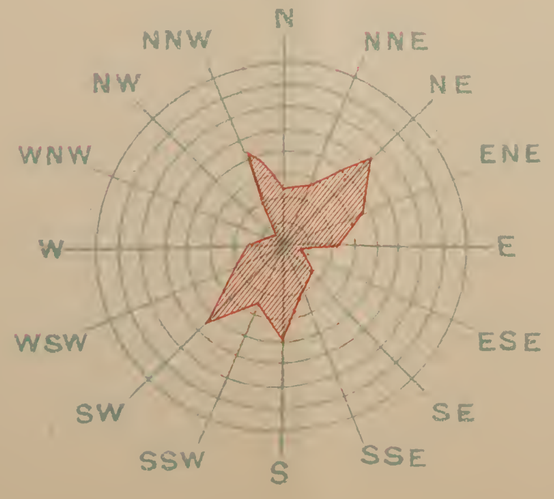
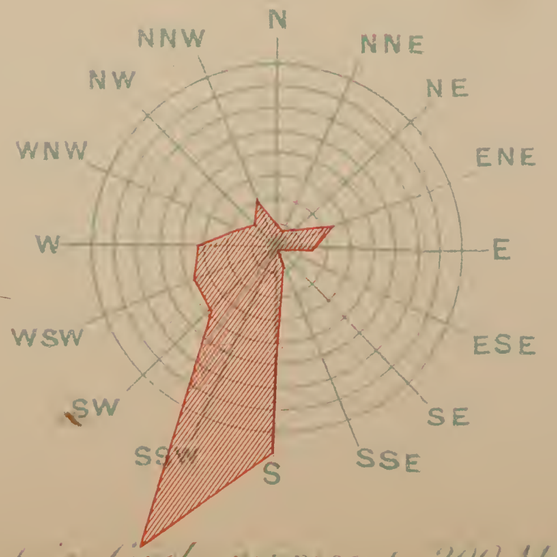


NOV.



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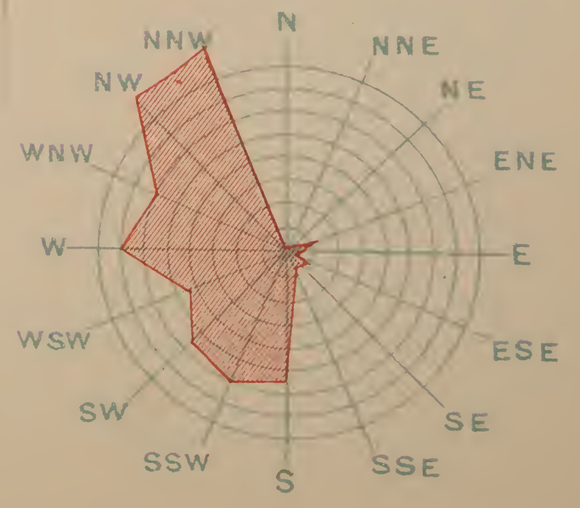

The Centre being Zero, each Concentric Circle represents 200 Miles.

Birmingham Philosophical Society.

REPORT PRESENTED BY THE COUNCIL

TO THE

ANNUAL MEETING OF MEMBERS,

HELD AT

MASON COLLEGE,

OCTOBER 19TH, 1893.

BIRMINGHAM

PRINTED AT THE HERALD PRESS, UNION STREET.

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REPORT

PRESENTED BY THE COUNCIL TO THE

ANNUAL MEETING OF MEMBERS,

HELD AT

MASON COLLEGE,

OCTOBER 19TH, 1893.

During the Session six General Meetings have been held, and the following papers communicated to the Society :—

1892.

Oct. 14 (Annual Meeting).—Professor Windle. * "The Modern University."

Nov. 16.—Mr. J. Humphreys. "The Flora of North-East Worcestershire."

Dec. 13.—Dr. W. W. J. Nicol. "The State of Chemistry before 1800.'

1893.

Feb. 15.—Professor Windle. * "The Physical Characters of the Boys of King Edward's School and Some Other Schools."

Professor H. S. Foxwell. "Bimetallism."

Mar. 16.—Mr. W. E. Collinge. * "Note on the Lateral Line System of *Polypterus*."

Professor Fiedler. "Glimpses into Teutonic Antiquity."

May 24.—Professor Fiedler. * "Contributions to a Life of John Lydgate, Monk and Poet, of Bury St. Edmunds."

Professor Tilden and Mr. G. E. Browne. "Early Iron Working in the Highlands of Scotland."

Mr. W. E. Collinge. * "The Lateral Canal System of *Lepidosteus osseus*."

June 14.—Professor Bridge. "The Suppression of the Hyoidean Cleft in certain Siluridæ."

Professor Bridge. "Warning Sounds in some Siluroid Fishes."

Professor Foxwell's paper on Bimetallism was a special address delivered at the invitation of the Council. Of the remaining papers, those indicted by an asterisk have been published in Vol. VIII., Part II., of the Society's Proceedings, which the Council have much pleasure in laying before the members.

The Council desire to give expression to their deep regret at the loss which the Philosophical Society has experienced by the death of one of its oldest and most valued members—Dr. H. W. Crosskey. Dr. Crosskey was one of the original promoters of the Society, filling in succession the offices of Secretary, Vice-President, and President, and to his ability and untiring energy in the earlier years of its history, the Society is largely indebted for its subsequent success. He has also contributed several valuable papers on Scientific and Educational subjects to the Society's proceedings. The Council would place on record their sense of the heavy loss which the scientific and educational work of the town has sustained by Dr. Crosskey's death.

Anthropometrical Committee.—The Council report that the chief work carried on in the Anthropometrical Laboratory during the past year has been in connection with the pupil teachers of the Birmingham School Board, of whom about one hundred have been examined. It is hoped that at the end of another year sufficient data will be forthcoming for a preliminary communication to the Society. Investigators have attended on two afternoons in the week, but the attendance of the general public at the Laboratory has been very small. It is to be feared that no material progress will be made in this direction until it becomes possible to engage the services of a permanent

investigator. In the meantime there is much work waiting to be done, and the Anthropometrical Committee would be glad to hear of any investigators who may be willing to devote some time each week to the work of the Laboratory.

The Meteorological Committee have again arranged with Mr. A. Cresswell for the publication, in Vol. VIII. Part II. of the Society's Proceedings, of a further series of records of the weather statistics of Birmingham.

Photographic Committee.—A number of Geological Photographs have been contributed by Mr. W. Jerome Harrison; and Professor Allen has taken several negatives, chiefly of the Carboniferous rocks in Somerset, from which prints will be made. Last year the number of photographs in hand was considered too small to offer to the British Association, but as several more subjects have been photographed during the past summer, the Photographic Committee will probably hand over to the Philosophical Society a suitable collection by the end of the present year.

The Council have quite recently sanctioned the formation of a section for the study and investigation of the Dialects and Folk-lore of the Midlands; and it is hoped that the results obtained by this section, together with those of the Anthropometric Committee, will contribute in a useful degree to the work being carried on by the Ethnographic Committee of the British Association.

The following grants have been made from the Endowment of Research Fund during the Session :—

Anthropometrical Committee... ...	£10	0	0
Meteorological Committee	10	0	0
Mr. W. E. Collinge (for researches in connection with the Lateral Canal System of Fishes).	10	0	0
Dr. G. Gore, F.R.S.	25	0	0

The regulations adopted by the Council with regard to the

distribution of this Fund will be found in an appendix to this Report.

Copies of the Society's Proceedings have been sent to the Societies and Libraries given in the appended list.

The Council desire to thank Mr. Landon for acting as Librarian, and also for his services as delegate at the meeting of the Midland Union of Natural History Societies at Birmingham. As a delegate from this Society, Mr. J. Kenward attended the annual meeting of the British Association at Nottingham, in September last, and for his services in this capacity the Council express their thanks.

The Council have also much pleasure in again tendering their thanks to the Medical Institute for the use of their rooms.

APPENDIX I.

Endowment of Research Fund. Regulations.

1.—Every applicant for aid from the Fund will be required to state specifically the purpose to which the money is to be applied.

2.—Every applicant to whom a grant is made will be expected to furnish to the Council, on or before the end of the Sessional year (June 30th), in which the grant was made, a report containing (*a*) a statement showing the results arrived at, or the stage which the inquiry has reached; (*b*) a general statement of the expenditure incurred.

[Forms of Application for grants from the Fund can be obtained from the Secretaries.]

APPENDIX II.

List of the Societies and Libraries to which Copies of the Proceedings are sent.

(The names of Societies interchanging publications are marked with an asterisk.)

Belfast .. .. .. *Natural History and Philosophical Society.
Birmingham .. .. Free Public Library.

BIRMINGHAM .. .. Mason College.
,, ... Medical Institute.
,, ... Midland Institute.
,, ... Natural History Society.
BRISTOL .. .. .. *Naturalists' Society.
BUCKHURST HILL, ESSEX *Essex Field Club.
CAMBRIDGE .. .. University Library.
,, ... *Philosophical Society.
DUBLIN .. .. .. Trinity College.
,, ... Royal Dublin Society.
,, ... Royal Irish Academy.
EDINBURGH .. .. University.
,, ... *Geological Society.
,, ... *Royal Physical Society.
,, ... *Royal Society.
FALMOUTH .. .. *Royal Cornwall Polytechnic Society.
GLASGOW .. .. University.
,, ... *Geological Society.
,, ... *Natural History Society.
,, ... *Philosophical Society.
HERTFORD .. .. *Hertfordshire Natural History Society.
LEICESTER .. .. *Philosophical and Literary Society.
LIVERPOOL .. .. *Biological Society.
,, ... *Literary and Philosophical Society.
LONDON .. .. .. *British Association for the Advancement of Science.
,, ... British Museum.
,, ... Chemical Society.
,, ... Entomological Society.
,, ... Geological Society.
,, ... Geological Survey,
,, ... Linnæan Society.
,, ... Natural History Museum, South Kensington.
,, ... *Physical Society.
,, ... *Royal Astronomical Society.
,, ... Royal Geographical Society.
,, ... *Royal Institution.
,, ... *Royal Society.
,, ... Society of Antiquaries.
,, ... Society of Arts.
,, ... University College.
,, ... *Zoological Society.

Manchester	*Geographical Society.
,, ...	Owens College.
,, ...	*Literary and Philosophical Society
,, ...	*Statistical Society.
Newcastle-upon-Tyne ..	*North of England Institute of Mining and Mechanical Engineers.
Nottingham	University College.
Oxford	Bodleian Library.
,, ...	Radcliffe Library.
Truro	*Royal Institution of Cornwall.
Austria—Prague ..	*Kœnigliche Böhmische Gess. der Wissen schaften.
,, Vienna ..	Kaiserliche Akademie der Wissenschaften.
Belgium—Brussels ..	*Académie Royale des Sciences.
,, ,, ..	*Société Entomologique de Belgique.
Calcutta	Asiatic Society.
Denmark—Copenhagen	Kongelige Danske Videnskabernes Selokab.
France—Paris	Académie des Sciences de l'Institut.
Germany—Berlin ..	Kœnigliche Akademie der Wissenschaften.
,, Munich ..	Kœnigliche Bayerische Akademie der Wissenschaften.
Italy—Bologna ..	*R. Accademia delle Scienze.
,, Naples	Società Reale, Accademia delle Scienze.
,, Rome	*Reale Accademia dei Lincei.
,, ,, ...	Biblioteca e Archivio Tecnico.
Melbourne	University Library.
Montreal	McGill College.
Nova Scotia—Halifax..	*Nova Scotian Institute of Natural Sciences.
Russia—Kiev	*Société des Naturalistes.
,, Moscow ..	*Société Impériale des Naturalistes.
,, St. Petersburg	Académie Impériale des Sciences.
South America—Buenos Ayres	Museo Publico.
Spain—Madrid	*Real Academia de Ciencias.
Switzerland—Geneva..	Société de Physique et d'Histoire Naturelle.
,, Lausanne	*Société Vaudoise des Sciences Naturelles.
Sydney, N. S. W. ..	*Royal Society.
,, ,, ..	*University Library.
,, ,, ..	*Australasian Association for Advancement of Science.

United States—

Baltimore ..	.. *Johns Hopkins University.
Boston ..	.. *American Academy of Science.
Cambridge ..	.. Harvard University.
Chapel Hill, N. C.	*Elisha Mitchell Scientific Society.
Charleston	.. *Elliot Society.
Philadelphia	.. *Academy of Natural Sciences.
Washington	.. Smithsonian Institute.
,,	.. *Bureau of Education.

BIRMINGHAM PHILOSOPHICAL SOCIETY.

GEOLOGICAL SECTION.

Report of the Committee for the Session 1892-93.

Four Ordinary Meetings have been held during the Session. The average number present was fifteen.

The Section contains forty-five members, of whom twenty-six were elected under Rule VII., Section 7.

At the Annual General Meeting held on November 10th, 1892, the following Officers were elected for the Session 1892-93 :—

Chairman—Professor Lapworth, LL.D., F.R.S.

Vice-Chairmen—Messrs. John Udall, F.G.S., and Wm. Sherwood, F.G.S.

Secretary—Mr. John Udall, F.G.S.

Committee—The Ex-Presidents, Rev. Dr. Crosskey, F.G.S., Mr. T. H. Waller, B.A., B.Sc., and Mr. J. Landon, F.G.S., with Messrs. W. Boulton, Assoc.R.S.M., C. Davison, M.A., W. J. Harrison, F.G.S., W. Sherwood, F.G.S., Walcot Gibson, F.G.S., and Dr. T. Stacey Wilson.

The following were the Meetings held, and the Papers read during the Session :—

1892.

Nov. 10.—Mr. J. Landon, F.G.S. "Geological Work in the Birmingham District."

Dec. 15.—Mr. W. Wickham King. "The Clent Hills Breccia."

1893.

Feb. 16.—Mr. W. Boulton, Assoc.R.S.M. "Some Recent Researches in the Igneous Rocks."

Mar. 23.—Dr. Lapworth, F.R.S. "Meaning and Bearing of the Pebbles of the District."

Birmingham Philosophical Society.

THE TREASURER IN ACCOUNT WITH THE ENDOWMENT OF RESEARCH FUND, FOR THE SESSIONAL YEAR 1892-93.

Receipts.

	£	s.	d.
Balance with Metropolitan and Birmingham Bank, Limited, 1st October, 1892	38	2	6
Subscriptions, viz.:—			
J. H. Chance 5 5 0			
R. L. Chance 3 3 0			
Miss J. K. Davies 2 2 0			
Follett Osler 3 3 0			
Alfred Hill 1 1 0			
	14	14	0
Dividends on £900 Birmingham Corporation Stock	30	13	0
	£83	9	6

Payments.

	£	s.	d.
Grant to Meteorological Committee...	10	0	0
,, Anthropometrical ,, ...	10	0	0
,, Mr. Walter E. Collinge, *re* the Lateral Canal System of Fishes...	10	0	0
,, Dr. Gore for Scientific Experiments ...	25	0	0
Balance with the Metropolitan Bank (of England and Wales), Limited	28	9	6
	£83	9	6

We have examined this Account with the books and vouchers of the Society, and find the same correct. We have also ascertained from the Bank of England that the Stock in which the fund is invested still stands in the names of the Trustees.

T. GILBERT GRIFFITHS, A.C.A.,
GEO. HERBERT SARGANT, F.C.A., } *Auditors.*

19th October 1893.

LIBRARY FUND.

Receipts.

	£	s.	d.
Balance in Treasurer's hands, 1st October, 1892 ...	£11	2	1
	£11	2	1

Payments.

	£	s.	d.
Chas. Griffin and Co., 1 Year Book of Societies ...	0	6	0
C. Cooper and Co., Limited, Binding	2	19	4
Balance in Treasurer's hands, 1st October, 1893 ...	7	16	9
	£11	2	1

	£	s.	d.
Balance of General Account	29	19	10
Balance of Library Fund	7	16	9
Balance due to Treasurer	£22	3	1

Examined and found correct.

T. GILBERT GRIFFITHS, A.C.A.,
GEO. HERBERT SARGANT, F.C.A., } *Auditors.*

Birmingham, 19th October, 1893.

THE TREASURER IN ACCOUNT WITH THE BIRMINGHAM PHILOSOPHICAL SOCIETY FOR THE SESSIONAL YEAR 1892-93.

RECEIPTS.

	£ s. d.	£ s. d.
General Department. Subscriptions, viz.:		
2 at £1 1 0 for 1891-92... ...	2 2 0	
93 at £1 1 0 for 1892-93... ...	97 13 0	
9 at £0 10 6 for 1892-93... ...	4 14 6	
		104 9 6
Geological Section. Subscriptions, viz.:		
1 at 5s. for 1891-92	0 5 0	
19 at 5s. for 1892-93	4 15 0	
		5 0 0
		109 9 6
Balance due to Treasurer, October, 1893		29 19 10
		£139 9 4

Subscriptions unpaid:—

4 at £1 1 0 General Department, 1891-92.
2 at 0 5 0 Geological Section, 1891-92.
7 at 1 1 0 General Department, 1892-93.
4 at 0 5 0 Geological Section, 1892-93.

PAYMENTS.

	£	s.	d.	£	s.	d.
Balance due to Treasurer, 1st October, 1892 ...				11	1	8
Wright, Dain, Peyton, and Co.:—						
Proceedings...	76	9	6			
Annual Reports, Circulars, &c. ...	14	0	6			
				90	10	0
Rent, one year to Midsummer, 1893				10	0	0
Secretaries' Expenses...				4	16	11
Midland Union of Natural History Societies, Subscription				1	7	3
Birmingham Daily Post, Advertising...				1	5	6
Birmingham Daily Gazette, „				0	19	6
Refreshments at Meetings, and Expenses in connection with Annual Meeting				5	4	6
Postages				1	5	0
Gratuity to Curator, £1; and Waitresses, 5s. ...				1	5	0
Honorarium to Mr. T. G. Johnson, Sub-Librarian...				5	5	0
Mr. S. P. Bolton, Donation towards Expenses of Entertaining the Midland Union of Natural History and Scientific Societies (Guarantee of £5)				4	15	0
Geological Section—Secretary's Expenses				0	3	6
Geological Section—Gratuity to Doorkeeper, Mason College				0	10	6
Travelling Expenses of Special Lecturer				1	0	0
				£139	9	4

Amount unpaid:—

Wright, Dain, Peyton, and Co., say £80.

We have examined these accounts with the books and vouchers of the Society, and have found them correct.

T. GILBERT GRIFFITHS, A.C.A.,
GEO. HERBERT SARGANT, F.C.A., } *Auditors.*

Birmingham, 19th October, 1893.

LIBRARY.

CATALOGUE OF JOURNALS, TRANSACTIONS, &c.

Annual Report of the Comptroller of the Currency to Congress, N. S. Boston (1885).

Architects' Register. Vol. ii. (1887).

Australasian Association for the Advancement of Science; Reports (1891—92).

Bagnall, J. E.; The Flora of Warwickshire (1891).

Baltimore, John Hopkins, University; Studies in Historical and Political Science. Vols. ii—x. (1885—93).

Birmingham Historical Society; Transactions. Vols. for 1880—84.

Birmingham Philosophical Society; Proceedings. Vols. i—viii. (1876—93).

Belfast Naturalists' Field Club; Reports (1884—90).

Belfast Natural History and Philosophical Society; Proceedings (1885—91).

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Boston, American Academy of Arts and Sciences. New series; vols. xx—xxvii. (1885—92).

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OFFICERS OF THE SOCIETY.

SESSION 1893-94.

President.

PROFESSOR R. S. HEATH, M.A., D.Sc.

Ex-Presidents.

REV. A. R. VARDY, M.A.
W. MATHEWS, M.A.
R. NORRIS, M.D.
W. A. TILDEN, D.Sc. Lond., F.R.S.
W. P. MARSHALL, M.I.C.E.
J. KENWARD, F.S.A.
REV. H. W. WATSON, D.Sc. CANTAB, F.R.S.
B. C. WINDLE, M.A., M.D.
J. H. POYNTING, D.Sc., F.R.S.

Vice-Presidents.

C. DAVISON, M.A.
T. W. BRIDGE, M.A.

Treasurer.

C. A. HARRISON, 22, WATERLOO STREET.

Secretaries.

J. LANDON, F.G.S., TRAINING COLLEGE, SALTLEY.
T. TURNER, ASSOC.R.S.M., F.I.C., MASON COLLEGE.

Other Members of Council.

F. J. ALLEN, M.A., M.B.
MISS COOPER.
MISS A. E. CLARK, M.D.
G. FIEDLER, Ph.D.
W. HILLHOUSE, M.A.
J. HUMPHREYS, L.D.S. F.L.S.
H. LEA.
F. W. MARTIN.
PRIESTLEY SMITH, M.R.C.S.
T. STACEY WILSON, B.Sc., M.D.

Trustees of the Endowment of Research Fund.

W. MATHEWS, M.A.
JAMES KENWARD, F.S.A.

BIRMINGHAM PHILOSOPHICAL SOCIETY.

ROLL OF MEMBERS,

OCTOBER, 1893.

Members of the Geological Section are marked (*).

	ELECTED.
Albright, G. S., M.A., The Elms, Edgbaston Park Road	1880
Allen, Prof. F. J., M.A., M.B. Cantab., Mason College	1887
Badger, E. W., *Midland Counties Herald Office* ...	1881
Barclay, J., B.Sc., Arncliffe, Cotton Lane, Moseley	1891
Barclay, T., 17 Bull Street	1881
Barham, F. F., Bank of England	1879
Barling, Prof. H. G., M.B., F.R.C.S., 85 Edmund Street	1886
Beale, C. G., Maple Bank, Church Road, Edgbaston	1876
Blake, J. G., M.D., Highfield Gate, Harborne Road	1876
Boeddicker, G. A., St. Mary's Road, Harborne ...	1881
Bolding, G. F., J.P., 224 Hagley Road	1887
*Boulton, W., Assoc.R.S.M., Mason College ...	1891
Bridge, Prof. M.A., Mason College (*Vice-President*)	1880
Bunce, J. Thackray, J.P., Longworth, Priory Road	1880
Burbidge, Rev. F. W., M.A., Training College, Saltley	1887
Carter, Eric M., 33 Waterloo Street	1888
Carter, A. H., M.D., F.R.C.P. (Lond.), Temple Row	1887
Carter, W. F., B.A., Union Club, Colmore Row ...	1885
Chance, John H., Augustus Road	1876

ELECTED.

Clark, Miss A. E., M.D., 4 Calthorpe Road ... 1879
Clayton, F. C., J.P,, Fernhill, 18 St. James's Road 1886
Collinge, W. E., Mason College 1893
Cooper, Miss A. J., High School for Girls, Edgbaston 1878
Couper-Coles, Sherard, 16 Adam Street, Manchester Square, London 1892
*Cullis, F. J., Sheephouse Road, Gloucester ... 1886
*Davison, Chas., M.A., King Edward's School, New Street (*Vice-President*) 1885
Deeley, John, Denmark House, Trafalgar Road, Moseley 1879
Dewes, H., 60 South Lambeth Road, London, S.W. 1886
Dixon, George, M.P., 42 Augustus Road, Edgbaston 1887
Docker, Dudley, The Cedars, King's Norton ... 1890
Docker, Mrs., The Cedars King's Norton 1890
Fiedler, Prof. G., Ph.D., Mason College 1892
Fulford, H. C., 35 Augustus Road 1876
Gore, George, LL.D., F.R.S., Broad Street ... 1876
Griffiths, E. T., M.D., The Warren, Washwood Heath, Birmingham 1886
Griffiths, T. Gilbert, Royal Chambers, Temple Row (*Auditor*) 1885
Grimley, C. F., Woodleigh, King's Norton 1878
Harris, W., J.P., 5 Vicarage Road, Edgbaston ... 1880
Harrison, C. A., 22 Waterloo Street (*Treasurer*) ... 1885
*Harrison, W. Jerome, F.G.S., Claremont Road ... 1881
Heath, Professor R. S., M.A., D.Sc., Mason College (*President*) 1885
Hendriks, H., 13 Frederick Road 1891
Hill, Alfred, J.P., 62 Hagley Road 1876
Hillhouse, Professor W., M.A., Mason College ... 1888
*Hipkins, W. E., 28 Wheeley's Road 1880
Hookham, G., M.A., The Mount, School Road, Moseley 1876
Hopkinson, John, D.Sc., M.A., F.R.S., Holmwood, Wimbledon, S.W.... 1876

ELECTED.

*Houghton, F. T. S., M.A., F.G.S., 188 Hagley Road, Edgbaston 1880

Housman, R. H., 61, Marloes Road, Kensington ... 1887

Humphreys, J., L.D.S.I., 22 Newhall Street ... 1886

Johnson, G. J., J.P., 136 Hagley Road 1879

Kenrick, G.H., Whetstone, Somerset Road, Edgbaston 1887

Kenward, J., F.S.A., Assoc.M.Inst.C.E., 280 Hagley Road 1876

*Landon, Joseph, F.G.S., The Training College, Saltley (*Secretary*) 1889

*Lapworth, Prof. C., LL.D., F.R.S., Mason College 1881

Lea, Henry, 38 Bennett's Hill 1878

Lea, John W., 38 Bennett's Hill 1887

Lee, E. H., B.A., 18 Newhall Street 1876

Levett, R., M.A., King Edward's School, New Street 1876

Lloyd, J. H., M.A., Ferndale, Carpenter Road ... 1880

MacCarthy, Rev. E. F. M., M.A., Hagley Road ... 1876

Manners-Smith, T., B.A., Queen's College... ... 1891

Marigold, J. Arthur, 3 Newhall Street 1888

Marshall, W. P., M.Inst.C.E., Richmond Hill, Edgbaston... 1876

*Martin, Fred. W., Rotton Park Road 1883

*Mathews, Miss, Highfield Lodge, Harborne Road ... 1888

*Mathews, W., M.A., 60 Harborne Road 1876

Mathews, G. S., M.A., Augustus Road 1876

Meyer, J. H. R., 3 Pakenham Road, Edgbaston ... 1887

Middlemore, John T., J.P., Brookfield, Belbroughton, Stourbridge 1886

Middlemore, Thomas, B.A., Holloway Head ... 1888

Myers-Ward, C. F., Mason College 1891

New, Herbert, 27 Wheeley's Road 1878

Norris, R., M.D., 3 Birchfield Road... 1876

Osler, H. F., Burcot Grange, near Bromsgrove ... 1892

Osler, Follett, F.R.S., South Bank, Edgbaston ... 1876

Parsons, C. T., J.P., Norfolk Road 1876

Phelps, Lieutenant-General A., 23 Augustus Road, Edgbaston 1888

	ELECTED.
Pickering, Mrs. Mary F., 83 Bloomsbury	1887
Pollack, Maurice, J.P., West View, Yardley ...	1882
Poynting, Prof. J. H., D.Sc., F.R.S., 11 St. Augustine's Road, Edgbaston	1880
Pumphrey, C., Southfield, King's Norton	1876
Rossiter, E. C., Langley Green	1892
Sargant, G. H., Temple Row (*Auditor*)	1887
*Sherwood, W., F.G.S., Eastbourne House, Sutton Coldfield	1891
Smith, Rev. A. Jamson, M.A., King Edward's Grammar School, Camp Hill	1884
Smith, Howard S., Waterloo Street...	1880
Smith, Priestley, M.R.C.S., 34 Paradise Street ...	1887
Southall, Alfred, Richmond Hill Road	1881
*Stone, Sir J. B., J.P., F.L.S., F.G.S., The Grange, Erdington	1891
*Thorley, E. F., The Cottage, Sutton Coldfield ...	1892
*Thornley, John E., Lyndon, Bickenhill	1889
Tilden, Prof. W. A., D.Sc., F.R.S., Mason College...	1880
Turner, Thos., Assoc. R.S.M., Mason College, (*Secretary*)	1886
*Udall, J., F.G.S., 21 Summer Hill Terrace ...	1878
Vardy, Rev. A. R., M.A., King Edward's School ...	1876
Walker, Thos. F., 220 Hagley Road	1887
Watson, Rev. H. W., M.A., D.Sc. Cantab., F.R.S., Berkswell, Coventry	1876
*Williams, S. de la Grange, Broome Close, Sutton Coldfield	1881
Windle, Prof. B. C. A., M.D., M.A., Mason College	1884
Wilson, J. E., J.P., Wyddrington, Edgbaston ...	1892
*Wilson, T. Stacey, B.Sc., M.D., Wyddrington, Edgbaston...	1887

Total, 109 Members.

It is requested that Notice of Change of Address, or of Resignation of Membership, be given to one of the Secretaries or to the Treasurer.

MEMBERS OF SECTIONS.

(Rule VII.)

GEOLOGY.

Badger, A. Bernard, M.A., 93 Oakfield Road, Balsall Heath.
Bagnall, J. E., A.L.S., 84 Witton Road, Aston.
Bayley, H., 299 Albert Road, Aston.
Bishop, Miss, 16 Harborne Road, Edgbaston.
Bloomer, H. H., Haughton Road, Handsworth.
Clerk, Dugald, F.C.S., A.M.I.C.E., Driffold, Sutton Coldfield.
Crisford, J. J., 172 Rotton Park Road, Edgbaston.
Dembski, F. E. L., 4 Windsor Terrace, Hagley Road.
Evans, A. T., S. Oswald's Road, Small Heath.
Gibson, Walcot, F.G.S., H. M. Geological Survey, London.
Greene, John, Four Oaks, Sutton Coldfield.
Harrison, W. J., Jun., 130 Linwood Road, Handsworth.
Hartshorne, Richard, Green Lane, Chester Road, Erdington.
Hooson, T. J. S., B.A., Bourne College, Quinton.
Impey, F. Paul, Longbridge, Northfield.
Johnstone, C. S., Board School, Floodgate Street.
King, William Wickham, Pedmore House, Stourbridge.
Last, Miss, 16 Harborne Road, Edgbaston.
Marston, C. F., A.M.I.C.E., Linthorpe, Sutton Coldfield.
Mutimer, A. A., M.A., Duchess Road, Edgbaston.
Patrick, D. H., The Training College, Saltley.
Proud, T. F., 11 Rotton Park Road, Edgbaston.
Stubbs, G. M., Ashfield, Park Road, Sutton Coldfield.
Titley, John, Sutton Coldfield.
Waller, T. H., B.A., B.Sc., 71 Gough Road, Edgbaston.
Walton, J. C., B.A., The Training College, Saltley.
Wilson, Miss A. D., Wyddrington, Edgbaston.

RULES.

I.

Name of the Society.

The Society shall be called "The Birmingham Philosophical Society."

II.

Objects of the Society.

The objects of the Society shall be to enable those engaged in the pursuit of any branch of Science or Philosophy (within the range of the subjects embraced by the British Association for the Advancement of Science, or such other subjects as may from time to time be approved by special vote of the Council) to communicate their researches to others ; to afford opportunities for those generally interested in Science to obtain a knowledge of the latest discoveries, and to assist them in following the course of modern investigations.

III.

Members.

The Society shall consist of three classes of Members—Ordinary, Corresponding, and Honorary.

Ordinary Members shall be such persons as are duly elected according to Rule IV.

Corresponding Members shall be persons not resident in Birmingham, who have rendered valuable service to the Society, or from whom important intelligence on scientific subjects may be expected.

Honorary Members shall be persons who have contributed in an eminent degree to the advancement of Science.

IV.

Ordinary Members.

Candidates shall be proposed in writing by two Members: intimation of such proposals shall be given to the Society in the

circular calling the next Ordinary Meeting, at which they shall be elected if they receive a majority of votes. The Secretary shall inform Members, by letter, of their election. With respect both to Entry-money and Annual Subscription, the Council shall have power to fix a special rate for Members of other scientific societies who may be elected as Members of the Philosophical Society; but the regular payments for Ordinary Members shall be the following:—

(1.) On and after such date as the Council may determine every Member upon admission shall pay One Guinea as Entry-money; if he fail to comply with the terms of this article within two months his election shall be void.*

(2.) The Annual Subscription to the Society shall be One Guinea, due in advance on the 1st October in each year. Members whose Subscriptions are in arrear for more than six months shall not have the power to vote on any question, nor be entitled to receive the printed *Proceedings* of the Society.

Members shall be held liable for their Annual Subscriptions until they have given to the Secretary written notice of their resignation.

V.

Corresponding Members.

Corresponding Members shall be recommended by a majority of the whole Council, and shall be elected in the same manner as Ordinary Members.

Corresponding Members shall not be required to pay any Entry-money or Annual Subscription. They shall each receive a copy of the *Proceedings* of the Society.

VI.

Honorary Members.

The number of Honorary Members shall not at any time exceed ten; not more than two to be elected in any one year. Honorary Members shall be recommended by a majority of the whole Council, and shall be elected in the same manner as Ordinary Members. They shall not be liable to any payments, and shall each receive a copy of the *Proceedings* of the Society.

VII.

Sections.

(1.) At the request of ten Members of the Society the Council shall have power to institute a Section, should they so determine, on any special subject within the scope of the objects of the Society.

---

* This rule is not yet enforced.

(2.) The Section shall, in the first instance, be formed of all Members of the Society who may intimate to the Secretaries their desire to join. Subsequently, each Section shall elect its own Members. Members of the Society may attend any Sectional Meetings; but the business of the Section shall be managed by its own Members.

(3.) Each Section shall elect a Chairman and Secretary of its own; and also may elect (if it think fit) a Committee of Management.

(4.) Each Section shall frame Rules for its own guidance subject to the following Regulations:—

1.—The Rules shall be submitted to the Council for approval.

2.—The announcements of the Meetings of the Section shall be made in the circulars calling the General Meetings of the Society.

3.—The Section shall report its proceedings yearly to the Society through the Council.

(5.) The Meetings of the Section shall be held on such days (*a*) as the Section may appoint and (*b*) the Council be able to arrange.

(6.) The Section shall submit to the Council such papers as it may desire to be published in the *Proceedings* of the Society; and the Council shall decide with respect to their publication according to the rules applicable to the papers read at the General Meetings.

(7.) Non-members of the Society shall be eligible as members of any Section on the payment of a subscription of 5s. per annum to the Society; but such Sectional Members shall not have the right of attending any Meetings except those of the Section for which they are enrolled, and shall not be entitled to receive any of the publications of the Society.

VIII.

Office-bearers.

The business of the Society shall be conducted by a Council, consisting of the President, the Ex-Presidents, two Vice-Presidents, a Treasurer, a Secretary or Secretaries, and ten other Members, to be elected as hereinafter prescribed; four to form a quorum. The Council shall appoint one of their number to act as Librarian.

IX.

Presidents and Vice-Presidents.

The President shall take the chair on all occasions when present. In absence of the President, one of the Vice-Presidents shall take the chair; when the President and Vice-Presidents

are absent, any Member may be voted into the chair. In case of an equality of votes, the Chairman shall have a casting vote in addition to his deliberative vote. The President shall be a Member, *ex-officio*, of all Committees.

X.

Secretaries.

The Secretary or Secretaries shall record the minutes, and conduct the general correspondence. He or they shall belong to all Committees of Council.

XI.

Treasurer.

The Treasurer shall have in charge the funds and all the property of the Society, and his accounts shall be annually audited by two Auditors appointed by the Annual Meeting.

The Treasurer shall also keep a Register of the names of the Members of the Society, which shall be presented at the Annual General Meeting, together with an inventory of all the property possessed by the Society.

XII.

Meetings.

The Regular Meetings shall be held between the months of October and June, the dates to be arranged by the Council. Other Meetings may be appointed by the Council. All Meetings shall be announced by circular, addressed to all the Members of the Society residing in the United Kidgdom.

The business shall, as a rule, proceed as follows; but its order may be varied should special circumstances, in the opinion of the Chairman, require an alteration :—

1.—Minutes of previous Meetings to be read and confirmed.
2.—New Members to be elected.
3.—Motions or general business to be disposed of.
4.—Papers to be read.
5.—Experiments, Specimens, or Scientific Apparatus to be exhibited.

A General Meeting shall be held annually. in October, on such day as the Council may appoint, due intimation of which shall be given to all Members of the Society.

At this General Meeting—

The Council shall give in a Report on the Proceedings of the Society during the past year.
The Treasurer shall exhibit an audited statement of the Funds of the Society.

Thereafter, the Society shall proceed to the election of Officers, and other members of the Council in the following order :—

1.—Election of President.
2.—Election of Vice-Presidents.
3.—Election of Treasurer.
4.—Election of Secretary.
5.—Election of Members of Council other than the preceding Office-bearers.
6.—Election of Auditors.

The retiring President shall then deliver an Address.

The Council shall nominate the Officers and other Members of the Council for the ensuing year. A list of such nominations shall be sent to Members twenty-one days before the Annual Meeting. Any Member wishing to propose an amendment to this list must do so by letter to the Secretaries seven days before the Annual Meeting. Notice of such amendments, if any, shall be sent to Members with the usual circular calling the Annual Meeting.

XIII.

Motions and Voting.

No motion shall be entertained at any regular Meeting unless notice of it has been given at the previous Meeting.

The Secretary or Secretaries shall insert such notice of motion in the circular calling the Meeting at which it will be brought forward.

Any motion may be carried by a simple majority of votes, except for the altering of, annulling, or adding to, the Rules.

XIV.

Alteration of Rules.

No motion for altering, annulling, or adding to, the Rules shall be entertained except at the Annual General Meeting, or be adopted, except by the votes of two-thirds of the Members present. Notice of such motion shall be given to the Council at least one month before the Annual Meeting, and be announced in the circular calling the Meeting.

XV.

Special General Meetings.

A Special General Meeting may be called by the Council. The Council shall be required to call such a Meeting at the request of ten Members of the Society. The special business to be transacted shall be announced in the circular calling the Meeting.

XVI.

Introduction of Friends.

Each Member shall have the privilege of introducing one friend to each Meeting of the Society. It shall be in the power of the President, however, to grant special permission to a Member to introduce more than one friend.

XVII.

Vacancies.

Vacancies arising among the Officers and Council during the currency of a year may be filled up, *ad interim*, by the Council, if they deem it expedient.

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